MAP I-1854

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGY OF THE BETHERA, CORDESVILLE, HUGER, AND KITTEREDGE QUADRANGLES BERKLEY COUNTY, SOUTH CAROLINA

By Robert E. Weems and Earl M. Lemon, Jr.

Prepared in cooperation with
U.S. NUCLEAR REGULATORY COMMISSION

WEEMS AND LEMON—GEOLOGY OF THE BETHERA, CORDESVILLE, HUGER, AND KITTEREDGE QUADRANGLES, SOUTH CAROLINA 1:24,000 MAP I-1854

MISCELLANEOUS INVESTIGATIONS SERIES
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DEPARTMENT OF THE INTERIOR
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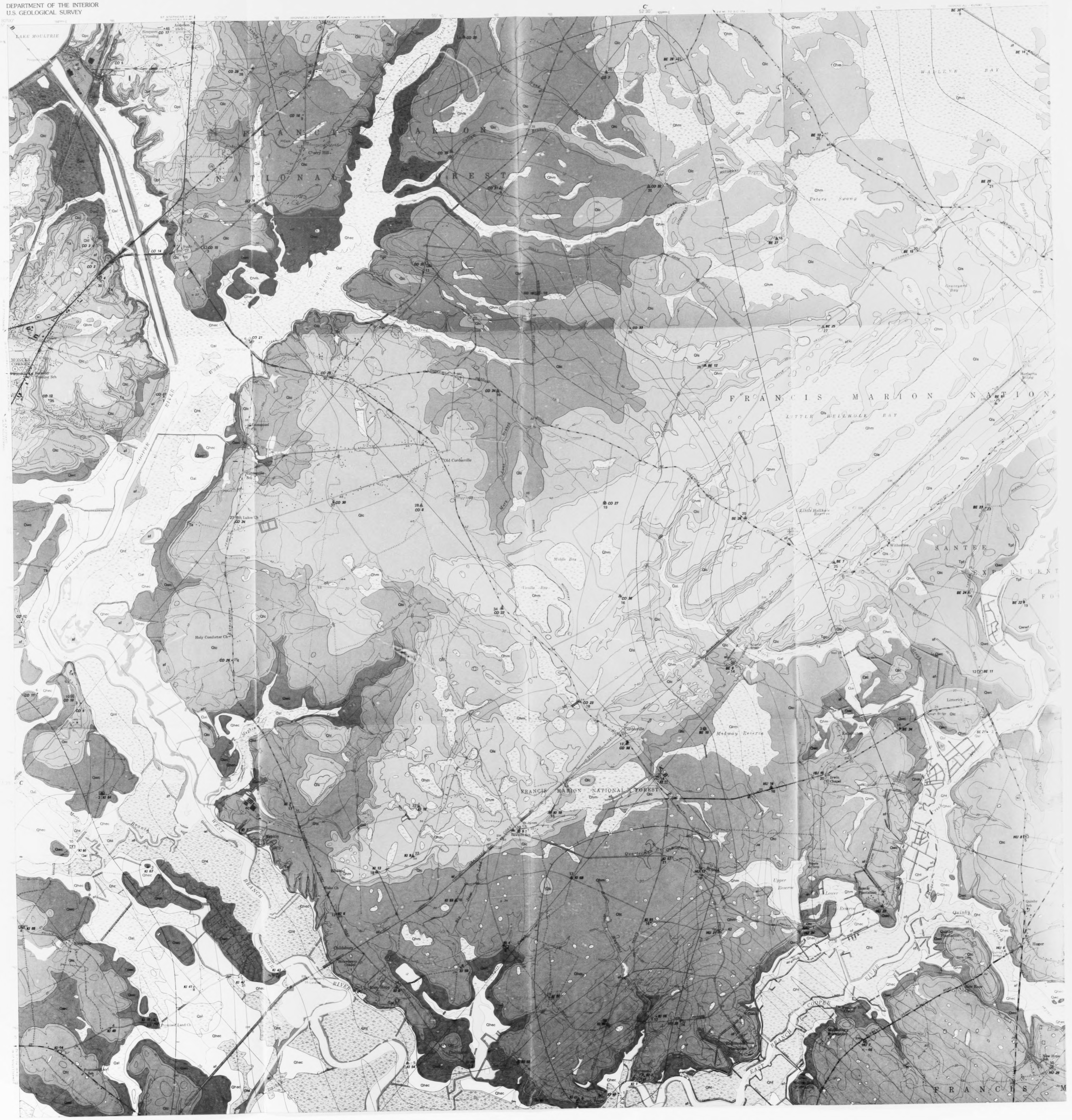

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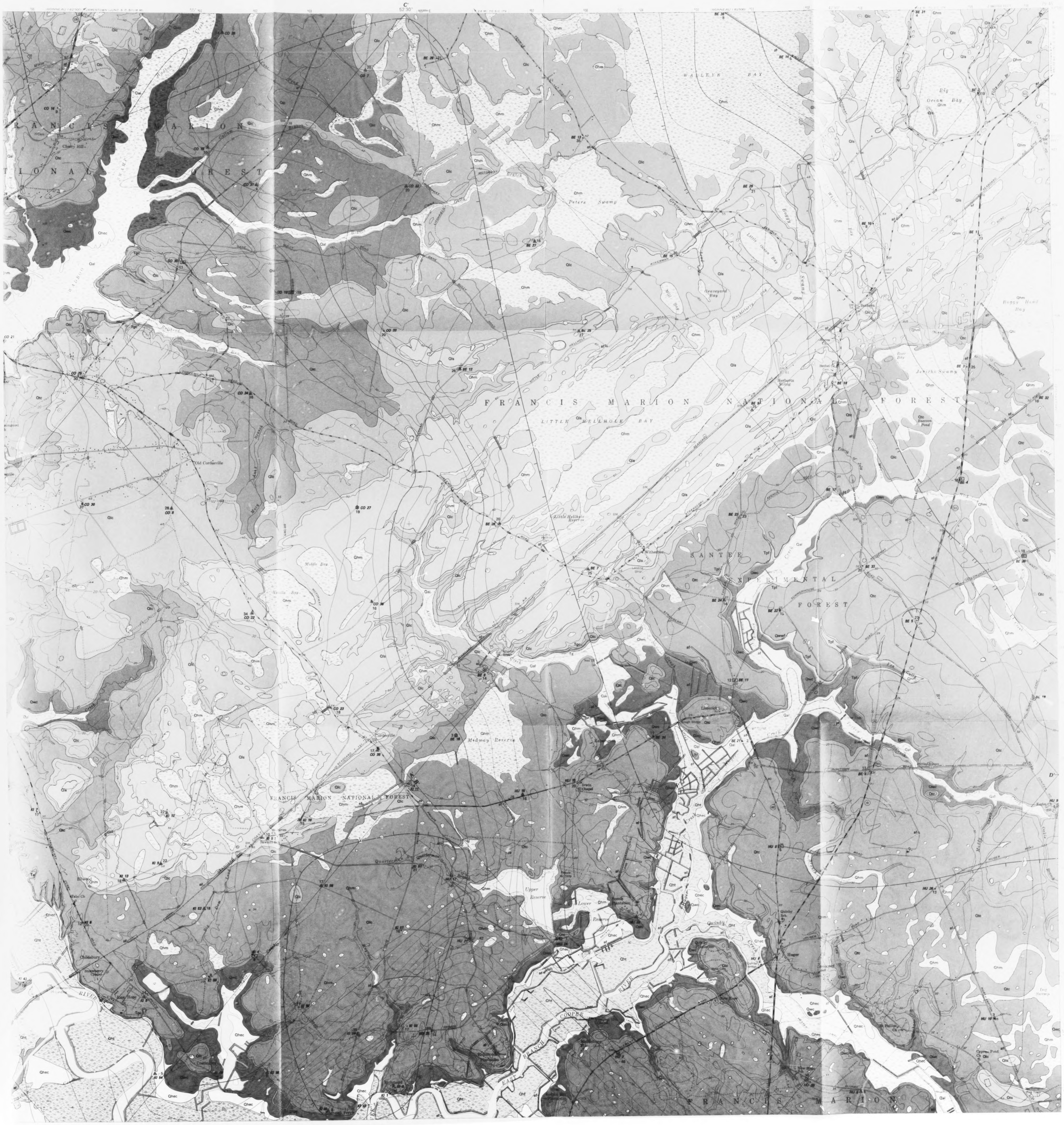
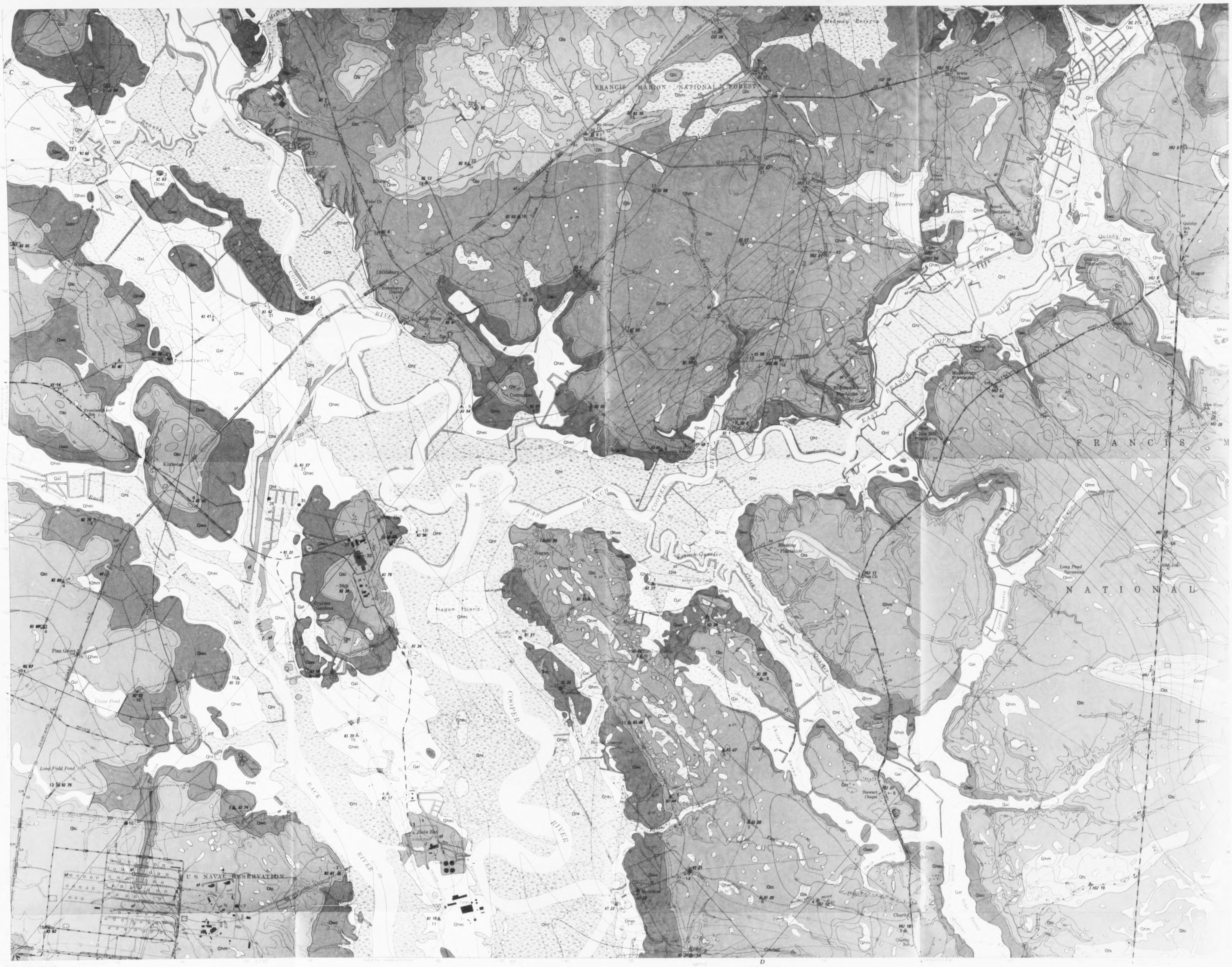
MISCELLANEOUS INVESTIGATIONS SERIES
I-1854 (SHEET 1 OF 2)



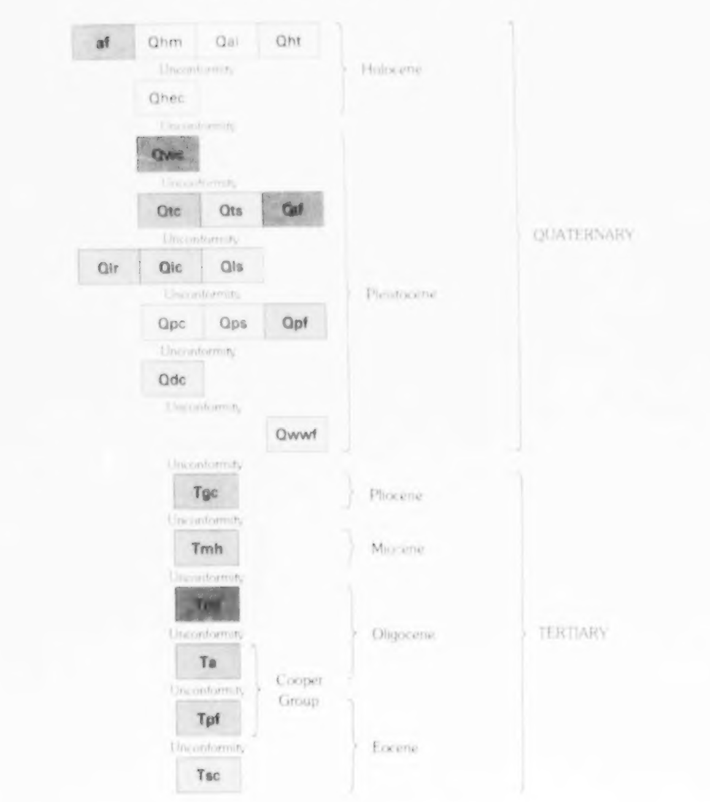


SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Base from U.S. Geological Survey, 1948 and 1960
Photorevised as of 1979
Polyconic projection. 1927 North American datum
10,000-foot grid based on South Carolina coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 17, shown in blue

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

A veneer of loose colluvium, 3–6 ft [illegible] covers most slopes; this veneer is not mapped. Color designations, in parentheses, are defined in Goddard and others (1948) and are based on naturally moist samples. Ages of deposits are given in years, ka (thousands of years), or Ma (millions of years).

af **Artificial fill**—Sand or clayey [illegible] of diverse origin, 3–10 ft (1–3 m) thick. Used as fill for roads, dams, and other construction

Qal **Alluvium (Holocene)**—Sands [illegible] migrating down drainage courses, frequently veneered by thin mucks and peats at their su[illegible]

Qht **Tidal marsh deposits (Holoc[illegible]**—Fine-grained, clean quartz sand, clayey sand, and clay, medium-gray (N5) to black [illegible] organic-rich. Dominant clay mineral is kaolinite, with significantly less illite/smectite [illegible]. Deposits are 0–10 ft (0–3 m) thick, and support marsh grass. Known ages are less than [illegible]

Qhec **Estuarine deposits (middle Holocene to Pleistocene*)**—Silty to sandy clay, and quartz sand, fine-grained, clayey, medium-g[illegible] to dark-gray (N3). Kaolinite is dominant clay mineral, with lesser amounts of illite/smectite [illegible]. Sediment is dewatered sufficiently to form firm ground. Deposits are 0–10 ft (0–3 m) th[illegible]

Qhm **Fresh water stream and swamp deposits (Holocene to Pleistocene (Wisconsinan glacial age))**—Peat and muck, thin, [illegible] (5YR3/4) to black (N1), accumulating along imponded stream courses and in ovoid-sh[illegible] depressions mostly on the Ladson and Ten Mile Hill terrace surfaces. Deposits located ma[illegible] from aerial photographs and topographic base. Known ages range from modern to at least 3[illegible]

Wando Formation (Pleistocene, about 70 to 130 ka)

Qwc Clayey sand and clay facies—[illegible] mottled pale-grayish-orange (10YR7/4) and medium-light-gray (N6), silty to sandy, [illegible] quartz sand, mottled pale-grayish-orange (10YR7/4) and medium-light-gray (N6). Fine [illegible] medium-grained. Dominant clay mineral is kaolinite, with illite and illite/smectite in variable proportions. Soil profile on this unit is poorly developed; color of B-horizon is grayish-yellow [illegible] to dark-yellowish-orange (10YR6/6) and the base of the B-horizon is usually 6 ft (2 m) deep. Unit covered, in places, by modern swamp deposits less than 3 ft (1 m) thick. Under[illegible] the Princess Anne terrace surface at elevations below 20 feet. Wood and terrestrial vertebr[illegible] indicate formation in estuarine to fluvial environments. Unit is up to 35 ft (11 m) thic[illegible]

Ten Mile Hill beds (informal) (Pleistocene, about 200 to 240 ka)

Qtc Clayey sand and clay facies—Clayey quartz sand, typically dark-yellowish-orange (10YR6/6) and (or) medium-light-gray (N6), less commonly medium-bluish-gray (5B5/1) or greenish-gray (5G6/1), black (N1) or moderate-reddish-brown (10R4/6), fine- to medium-grained, poorly sorted, and silty to sandy clay, with same color distribution as the sand and locally moderate red (5R4/6) where deeply weathered. Dominant clay minerals are kaolinite, illite/smectite and illite in variable proportions. Soil profile moderately well developed. B-horizon is typically yellowish orange (10YR6/6) to reddish orange (10YR6/6) and 6–10 ft (2–3 m) deep. Underlies the lower Talbot terrace at elevations below 40 ft (12 m) and usually above 15 ft (4.5 m). Wood and terrestrial vertebrate fossils indicate deposition in fluvial to estuarine environments. Unit is up to 65 ft (20 m) thick

Qts Clean sand facies—Quartz sand, dark-yellowish-orange (10YR6/6), fine- to medium-grained, abundant very fine-grained, dark, heavy minerals present below soil profile, conspicuously crossbedded. Dominant clay minerals are kaolinite and vermiculite. Occurs only in the far southeast part of the map area, mostly at elevations between 35 and 50 ft (10 and 15 m). Unit is up to 50 ft (15 m) thick

Qtf Fossiliferous sand facies—Quartz sand, medium-gray (N5), fine- to medium-grained, silty, micaceous, very fine-grained heavy minerals sparsely present; shells moderately to abundantly present (mostly *Mulinia* and some oyster). Present only in subsurface of the southeastern corner of the map area (HU-3, section *B*-*B*′). Unit up to 10 ft (3 m) thick

Ladson Formation (Pleistocene, between 240 and 730 ka)

Qlr Pebbly, coarse sand facies—Feldspathic pebbly quartz sand, medium-gray (N5), very poorly sorted, subrounded to subangular. Present only in the subsurface in the deep channel crossing the Bethera quadrangle. Probably represents a prehistoric channel of the Santee River. Unit is up to 40 ft (12 m) thick. Present only in subsurface

Qlc Clayey sand and clay facies—Clayey quartz sand, moderate-reddish-brown (10YR4/6), moderate-red (5R4/6) and (or) medium-light-gray (N6), medium-grained, poorly sorted, and silty to sandy clay. Dominant clay minerals are kaolinite, illite/smectite, and illite in variable proportions. Soil profile is well developed; B-horizon is moderate reddish brown (10R4/6) to dark reddish brown (10R3/4) and 10–15 ft (3–4 m) deep. Underlies the upper Talbot terrace at elevations between 35 and 55 ft (10 and 16 m). Terrestrial vertebrate fossils locally present. Probably accumulated in fluvial, estuarine, and lagoonal environments. Unit is up to 35 ft (10 m) thick

Qls Clean sand facies—Quartz sand, dark-yellowish-orange (10R6/6), coarse-grained, poorly sorted, abundant fine-grained, dark, heavy minerals below soil profile, conspicuously crossbedded. Dominant clay minerals are kaolinite and vermiculite, with reworked gibbsite forming detrital clay balls at base. Occurs mostly at elevations between 50 and 65 ft (15 and 20 m). Probably formed as a barrier island. Unit is up to 20 ft (6 m) thick

Penholoway Formation (Pleistocene, between 730 and 970 ka)

Qpc Clayey sand and clay facies—Silty to sandy clay, medium-gray (N5) to medium-bluish-gray (5B5/5), weathers to very light gray (N8), frequently well laminated. Dominant clay minerals are kaolinite, illite/smectite, and illite in variable proportions. Probably accumulated in an open lagoonal environment. Soil profile well developed; B-horizon ranges from moderate reddish brown (10R4/6) to mottled dark reddish brown (10R3/4) and light grey (N7) and is 10–15 ft (3–5 m) deep. Unit is up to 15 ft (5 m) thick

Qps Clean sand facies—Quartz sand, moderate-reddish-brown (10R4/6) to dark-yellowish-orange (10R6/6), medium- to coarse-grained, abundant fine-grained, dark, heavy minerals below soil profile; conspicuously crossbedded. Probably deposited as part of a coastal barrier island. Dominant clay minerals are kaolinite and vermiculite, with reworked gibbsite forming detrital clayballs at base. Unit not over 6 ft (2 m) thick in this map area

Qpf Fossiliferous sand facies—Quartz sand, medium-gray (N5) to medium-bluish-gray (5B5/1) or greenish-gray (5G6/1), fine- to medium-grained, phosphatic, bioturbated. Dominant clay minerals are kaolinite, illite/smectite, and illite in decreasing order of abundance. Unweathered beds contain a moderately diverse molluscan fossil fauna, so this unit probably formed as a shallow-marine shelf deposit. Basal contact usually marked by a 1- to 3-in. (3- to 8-cm) thick layer of coarse-grained sand, black phosphate pebbles, and worn and rounded bones and teeth. Unit is probably up to 30 ft (9 m) thick

Daniel Island beds (Pleistocene, between 0.73 and 1.6 Ma)

Qdc Clayey sand and clay facies—Clayey sand and silty to sandy clay, dark-bluish-gray (5B3/1) to dark-gray (N3), sands fine- to medium-grained, and dark brownish-gray (5YR3/1) peats, dense, often sticky. Probably deposited in estuarine to lagoonal environments. Present only in subsurface channels. Unit up to 50 ft (15 m) thick

Waccamaw Formation (Pleistocene, between 1.25 and 1.65 Ma)

Qwwf Fossiliferous sand facies—Quartz sand, medium-gray (N5) to medium yellowish orange (10R7/6), fine- to medium-grained, shelly, phosphatic, bioturbated. Dominant clay minerals are kaolinite, illite/smectite, and illite in decreasing order of abundance. Unweathered beds contain a diverse mollusk fossil fauna. Basal contact usually marked by a 1- to 2-in. (3- to 5-cm) thick layer of coarse-grained sand, black phosphate pebbles, and worn and rounded bones and teeth. Unit is up to 25 ft (8 m) thick. Present at surface only in the Bethera quadrangle and in the subsurface of the Cordesville and Huger quadrangles

Tgc **Goose Creek Limestone (Pliocene, about 3.5 Ma)**—Quartzose and phosphatic calcarenite, very pale orange (10YR8/2) (wet) to chalk-white (dry), medium- to coarse-grained, sparsely shelly. Dominant clay minerals are kaolinite and illite/smectite. Basal contact marked by a 1- to 4-in. (3- to 10-cm) thick layer of black, rounded, modally 1–2 in. (4–5 cm) diameter phosphate pebbles. Unit up to 50 ft (15 m) thick

Tmh **Marks Head Formation (Miocene, about [illegible]** [illegible] contact with the underlying Ashley [illegible] diameter, subrounded phosphate pebbles [illegible] known to be 2 ft (0.7 m) thick in this area [illegible] shown only on cross section *B*-*B*′

Tcb **Chandler Bridge Formation (Oligocene, a[illegible]** [illegible] weathers to medium gray (N5) [illegible] with lesser amounts of illite and [illegible] Basal contact with the underlying Ashley For[illegible] unconformity. Vertebrate remains are abund[illegible] this area, only found in subsurface of Cordesv[illegible]

Ta **Ashley Formation of the Cooper Group (**[illegible] brown (5YR3/4), fine-grained, phosphatic [illegible] small amounts of sepiolite and attapulgite [illegible] pebble bed (1–4 in. or 3–10 cm thick) [illegible] sparsely macrofossiliferous but [illegible] m thick

Tpf **Parkers Ferry Formation of the Cooper Gr[illegible]** grained, calcarenite, light blue [illegible] plastic, dense, sticky. Dominant [illegible] 1–2 ft (0.3–0.7 m) of [illegible] sand. Contains numerous [illegible] m) thick

Tsc **Cross Member of the Santee Limestone** [illegible] grained, yellowish gray (5Y7/2) [illegible] Macrofossil fragments locally [illegible] usually present. Unit is up to [illegible] *B*-*B*′, *C*-*C*′, and *C*′-*D* [illegible]

*Note: In early 1987, a [illegible] the Fort Moultrie quadrangle [illegible] 33,070 ± 1830 years [illegible] 201,860 indicates that [illegible] 3 of Shackleton and Opdyke [illegible] latest Pleistocene in age

GEOLOGY OF THE BETHERA, CORDESVILLE, HUGER, AND KITTREDGE QUADRANGLES, BERKELEY COUNTY, SOUTH CAROLINA

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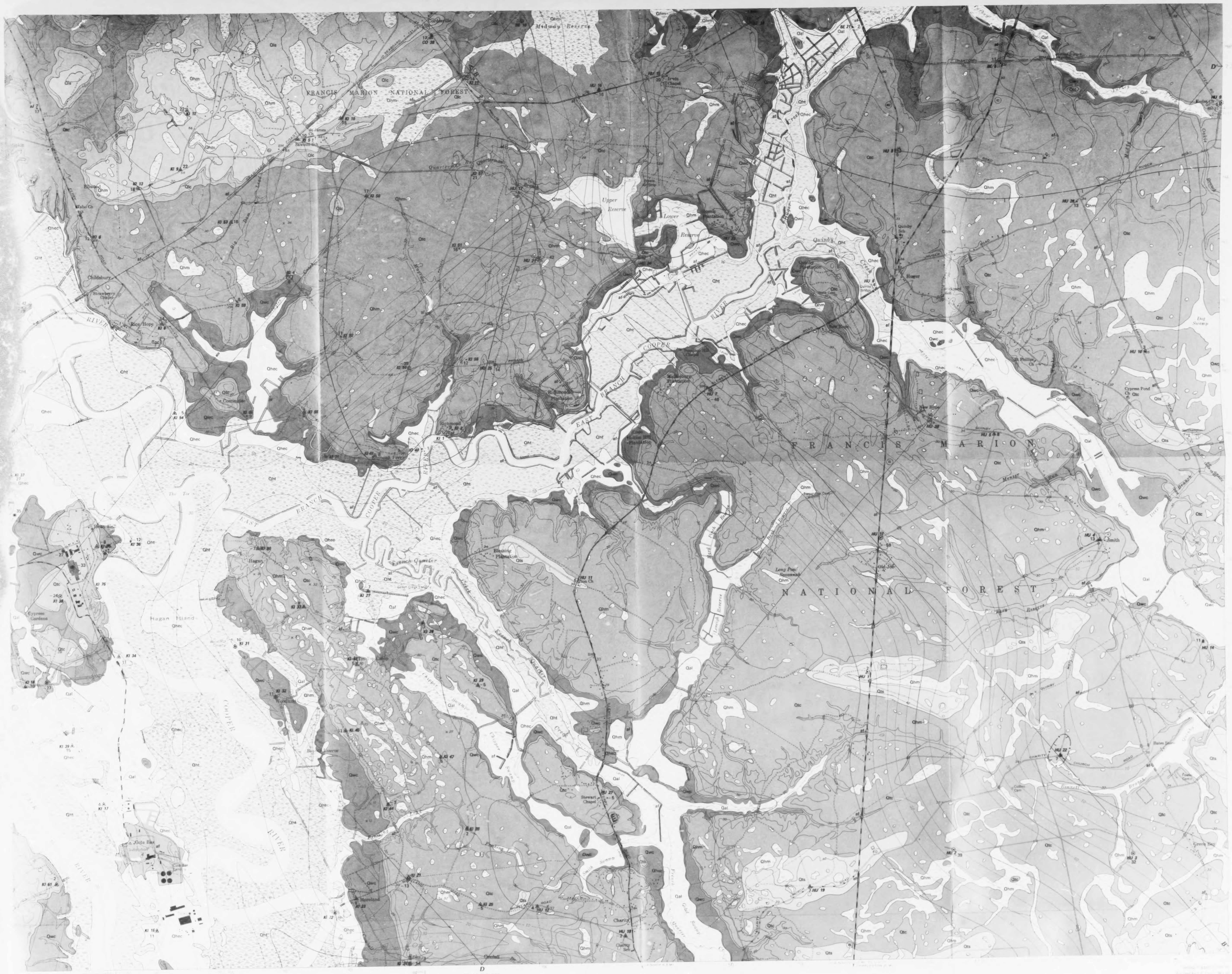

D

SCALE 1:24 000

1 ½ 0 1 MILE

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

[illegible]ION OF MAP UNITS

[illegible] most slopes, this veneer is not mapped. Color [illegible] others (1948) and are based on naturally moist [illegible] (years), or Ma (millions of years)

[illegible] range 3–10 ft (1–3 m) thick. Used as fill for roads.

[illegible] coming down drainage courses, frequently veneered by

[illegible] clean quartz sand, clayey sand, and clay, [illegible] rich. Dominant clay mineral is kaolinite, with [illegible] are 0–10 ft (0–3 m) thick, and support marsh

[illegible] Pleistocene?)—Silty to sandy clay, and quartz sand, [illegible] gray (N3). Kaolinite is dominant clay mineral, with [illegible] is dewatered sufficiently to form firm ground.

[illegible] (Holocene to Pleistocene (Wisconsinan glacial [illegible] to black (N1), accumulating along impounded [illegible] mostly on the Ladson and Ten Mile Hill terrace [illegible] photographs and topographic base. Known ages

[illegible] to 130 ka)
[illegible] pale grayish orange (10YR7/4) and medium-light- [illegible] sand, mottled pale-grayish-orange (10YR7/4) and [illegible] grained. Dominant clay mineral is kaolinite, with illite [illegible] Soil profile on this unit is poorly developed; color [illegible] yellowish-orange (10YR6/6) and the base of the [illegible] covered, in places, by modern swamp deposits less [illegible] Anne terrace surface at elevations below 20 feet. [illegible] indicate formation in estuarine to fluvial environments.

Ten Mile Hill beds (informal) (Pleistocene, about 200 to 240 ka)

Qtc Clayey sand and clay facies—Clayey quartz sand, typically dark-yellowish-orange (10YR6/6) and (or) medium-light-gray (N6), less commonly medium-bluish-gray (5B5/1) or greenish-gray (5G6/1), black (N1) or moderate-reddish-brown (10R4/6), fine- to medium-grained, poorly sorted, and silty to sandy clay, with same color distribution as the sand and locally moderate red (5R4/6) where deeply weathered. Dominant clay minerals are kaolinite, illite/smectite and illite in variable proportions. Soil profile moderately well developed. B-horizon is typically yellowish orange (10YR6/6) to reddish orange (10YR6/6) and 6–10 ft (2–3 m) deep. Underlies the lower Talbot terrace at elevations below 40 ft (12 m) and usually above 15 ft (4.5 m). Wood and terrestrial vertebrate fossils indicate deposition in fluvial to estuarine environments. Unit is up to 65 ft (20 m) thick

Qts Clean sand facies—Quartz sand, dark-yellowish-orange (10YR6/6), fine- to medium-grained, abundant very fine-grained, dark, heavy minerals present below soil profile, conspicuously crossbedded. Dominant clay minerals are kaolinite and vermiculite. Occurs only in the far southeast part of the map area, mostly at elevations between 35 and 50 ft (10 and 15 m). Unit is up to 50 ft (15 m) thick

Qtf Fossiliferous sand facies—Quartz sand, medium-gray (N5), fine- to medium-grained, silty, micaceous, very fine-grained heavy minerals sparsely present; shells moderately to abundantly present (mostly *Mulinia* and some oyster). Present only in subsurface of the southeastern corner of the map area (HU–3, section **B′-B″**). Unit up to 10 ft (3 m) thick

Ladson Formation (Pleistocene, between 240 and 730 ka)

Qlr Pebbly, coarse sand facies—Feldspathic pebbly quartz sand, medium-gray (N5), very poorly sorted, subrounded to subangular. Present only in the subsurface in the deep channel crossing the Bethera quadrangle. Probably represents a prehistoric channel of the Santee River. Unit is up to 40 ft (12 m) thick. Present only in subsurface

Qlc Clayey sand and clay facies—Clayey quartz sand, moderate reddish-brown (10YR4/6), moderate red (5R4/6) and (or) medium-light-gray (N6), medium-grained, poorly sorted, and silty to sandy clay. Dominant clay minerals are kaolinite, illite/smectite, and illite in variable proportions. Soil profile is well developed. B-horizon is moderate reddish brown (10R4/6) to dark reddish brown (10R3/4) and 10–15 ft (3–4 m) deep. Underlies the upper Talbot terrace at elevations between 35 and 55 ft (10 and 16 m). Terrestrial vertebrate fossils locally present. Probably accumulated in fluvial, estuarine, and lagoonal environments. Unit is up to 35 ft (10 m) thick

Qls Clean sand facies—Quartz sand, dark yellowish-orange (10R6/6), coarse-grained, poorly sorted, abundant fine-grained, dark, heavy minerals below soil profile, conspicuously crossbedded. Dominant clay minerals are kaolinite and vermiculite, with reworked gibbsite forming detrital clay balls at base. Occurs mostly at elevations between 50 and 65 ft (15 and 20 m). Probably formed as a barrier island. Unit is up to 20 ft (6 m) thick

Penholoway Formation (Pleistocene, between 730 and 970 ka)

Qpc Clayey sand and clay facies—Silty to sandy clay, medium-gray (N5) to medium-bluish-gray (5B5/5), weathers to very light gray (N8), frequently well laminated. Dominant clay minerals are kaolinite, illite/smectite, and illite in variable proportions. Probably accumulated in an open lagoonal environment. Soil profile well developed. B-horizon ranges from moderate reddish brown (10R4/6) to mottled dark reddish brown (10R3/4) and light gray (N7) and is 10–15 ft (3–5 m) deep. Unit is up to 15 ft (5 m) thick

Qps Clean sand facies—Quartz sand, moderate-reddish-brown (10R4/6) to dark yellowish-orange (10R6/6), medium- to coarse-grained, abundant fine-grained, dark, heavy minerals below soil profile, conspicuously crossbedded. Probably deposited as part of a coastal barrier island. Dominant clay minerals are kaolinite and vermiculite, with reworked gibbsite forming detrital clayballs at base. Unit not over 6 ft (2 m) thick in this map area

Qpf Fossiliferous sand facies—Quartz sand, medium-gray (N5) to medium bluish-gray (5B5/1) or greenish-gray (5G6/1), fine- to medium-grained, phosphatic, bioturbated. Dominant clay minerals are kaolinite, illite/smectite, and illite in decreasing order of abundance. Unweathered beds contain a moderately diverse molluscan fossil fauna, so this unit probably formed as a shallow-marine-shelf deposit. Basal contact usually marked by a 1-to-3-in. (3-to-8-cm) thick layer of coarse-grained sand, black phosphate pebbles, and worn and rounded bones and teeth. Unit is probably up to 30 ft (9 m) thick

Daniel Island beds (Pleistocene, between 0.73 and 1.6 Ma)

Qdc Clayey sand and clay facies—Clayey sand and silty to sandy clay, dark-bluish-gray (5B3/1) to dark-gray (N3), sands fine- to medium-grained, and dark-brownish-gray (5YR3/1) peats, dense, often sticky. Probably deposited in estuarine to lagoonal environments. Present only in subsurface channels. Unit up to 50 ft (15 m) thick

Waccamaw Formation (Pleistocene, between 1.25 and 1.65 Ma)

Qwwf Fossiliferous sand facies—Quartz sand, medium-gray (N5) to medium yellowish-orange (10R7/6), fine- to medium-grained, shelly, phosphatic, bioturbated. Dominant clay minerals are kaolinite, illite/smectite, and illite in decreasing order of abundance. Unweathered beds contain a diverse mollusk fossil fauna. Basal contact usually marked by a 1-to-2-in. (3-to-5-cm) thick layer of coarse-grained sand, black phosphate pebbles, and worn and rounded bones and teeth. Unit is up to 25 ft (8 m) thick. Present at surface only in the Bethera quadrangle and in the subsurface of the Cordesville and Huger quadrangles

Tgc **Goose Creek Limestone (Pliocene, about 3.5 Ma)**—Quartzose and phosphatic calcarenite, very pale-orange (10YR8/2) (wet) to chalk-white (dry), medium- to coarse-grained, sparsely shelly. Dominant clay minerals are kaolinite and illite/smectite. Basal contact marked by a 1-to-4-in. (3-to-10-cm) thick layer of black, rounded, modally 1–2 in. (3–5 cm) diameter phosphate pebbles. Unit up to 50 ft (15 m) thick

Tmh **Marks Head Formation (Miocene, about 18 Ma)**—Quartz phosphate sand, grayish-olive (10Y4/2) or olive-gray (5Y3/2) to moderate olive brown (5Y4/4), fine-grained, contains attapulgite. Basal contact with the underlying Ashley Formation (Ta) marked by sparse, 0.5–1.0 in. (1–3 cm) diameter, subrounded phosphate pebbles. Vertebrate remains are locally abundant. Unit only known to be 2 ft (0.7 m) thick in this area. Present only in subsurface of the Huger quadrangle; shown only on cross section **B′-B″**

[illegible] **Chandler Bridge Formation (Oligocene, about 28 Ma)**—Quartz phosphate sand, dusky-green (5G3/2), weathers to medium-gray (N5), very fine- to fine-grained. Dominant clay mineral is illite/smectite with lesser amounts of illite and kaolinite; sepiolite occurs in the basal few centimeters. Basal contact with the underlying Ashley Formation (Ta) is marked by a burrowed, gently rolling unconformity. Vertebrate remains are abundant. Unit not known to be over 3 ft (1 m) thick in this area, only found in subsurface at localities *CO-10*, *KI-62*, and *KI-75*

Ta **Ashley Formation of the Cooper Group (Oligocene, about 30 Ma)**—Calcarenite, light olive-brown (5Y5/6), fine-grained, phosphatic, massive. Dominant clay mineral is illite/smectite, with lesser amounts of sepiolite and attapulgite. Base of unit contains densely packed phosphate pebble bed (1–4 in. or 3–10 cm thick), with pebbles modally 1–2 in. (3–5 cm) in diameter. Sparsely macrofossiliferous but sand-size foraminifera tests are abundant. Unit is up to 125 ft (38 m) thick

Tpf **Parkers Ferry Formation of the Cooper Group (Eocene, about 38 Ma)**—Calcilutite to very fine-grained calcarenite, light-blue-green (5BG6/6) to moderate-yellowish-green (10GY6/4), stiff to plastic, dense, sticky. Dominant clay mineral is illite/smectite; lesser amounts of clinoptilolite. Basal 1–2 ft (0.3–0.7 m) of unit often black (N1) and composed mostly of phosphate and glauconite sand. Contains numerous (0.25–0.50 in. or 0.6–1.2 cm) echinoid spines. Unit is over 65 ft (20 m) thick

Tsc **Cross Member of the Santee Limestone (Eocene, about 44 Ma)**—Calcarenite, very fine-grained, yellowish-gray (5Y1/2) to light gray (N7), friable but tough, some beds firmly cemented. Macrofossil fragments locally abundant. Small amounts (1–5 percent) of glauconite and phosphate usually present. Unit is up to 125 ft (38 m) thick. Present only in subsurface (see sections **A-A′**, **B-B′**, **C-C′**, and **C′-D′**)

*Note: In early 1987, a detrital beach flotsam bed was found at the base of unit (Qhec) in the Fort Moultrie quadrangle (see figure 1). A radiocarbon date of this material of 33,070 ± 1830 years (Beta Laboratory, Coral Gables, Fla., laboratory report B-20188) indicates that some parts of this deposit are as old as mid-Wisconsinan (stage 3 of Shackleton and Opdyke, 1973); therefore, this unit is now known to be partly latest Pleistocene in age

EXPLANATION OF MAP SYMBOLS

Contact—Located by changes in slope and by projecting drill-hole data to surface

Structure contours—Drawn on base of Quaternary units. Contour interval is 10 ft. Datum is mean sea level

Updip limit of the Parkers Ferry Formation beneath Pleistocene cover—Tick marks point downdip

Updip limit of the Ashley Formation beneath Pleistocene cover—Tick marks point downdip

Outlier of Marks Head Formation

Drill holes, boreholes, and outcrops—Initials represent quadrangle name: ***BE*** Bethera, ***CO*** Cordesville, ***HU*** Huger, ***KI*** Kittredge. Value indicates elevation (in feet) above sea level of the base of the Pleistocene (where known). See Weems and Lemon (1985) for descriptions

KI 16 • 11 Drill hole
KI 2 × Outcrop
▣ Borehole—Location from unpublished engineering reports
☐ Chandler Bridge Formation encountered
[illegible] Marks Head Formation encountered
△ Goose Creek Limestone encountered
[illegible] Waccamaw Formation encountered
[illegible] Daniel Island beds encountered
○ Penholoway Formation outliers encountered
▭ Ladson Formation outliers encountered

Active sand and clay pits

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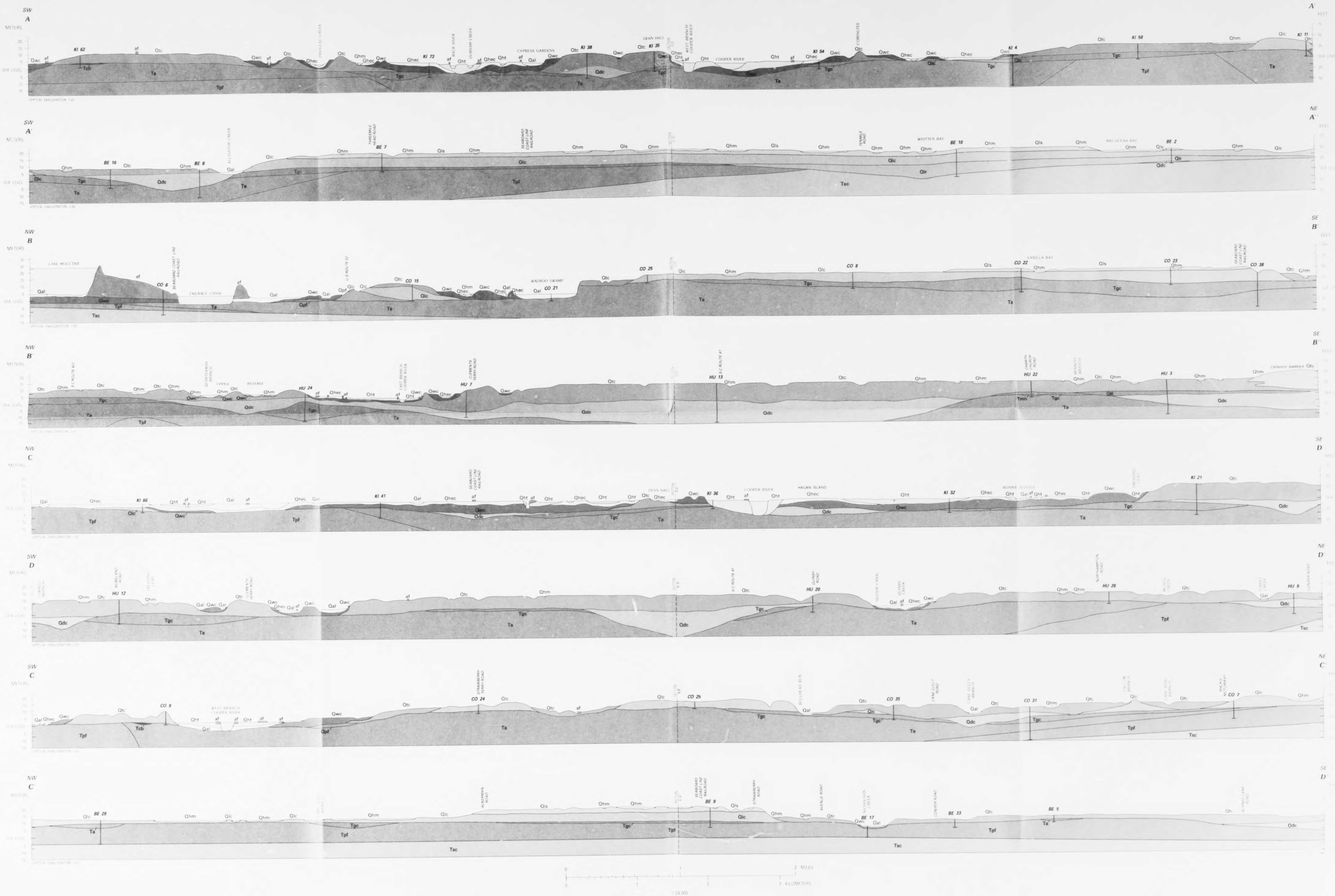

INTRODUCTION

The Bethera, Cordesville, Huger, and Kittredge quadrangles, an area of about 200 sq mi (650 sq km), are located in the outer Atlantic Coastal Plain about midway between the Cape Fear Arch (to the northeast) and the Southeast Georgia Embayment (to the southwest). Marine, marginal-marine, and fluvial-estuarine sediments, ranging in age from middle Eocene to Holocene, crop out or are present just beneath the land surface in these quadrangles. The area is generally low and flat, especially where underlain by upper Quaternary deposits along the Cooper River and its tributaries. In the northwestern and northeastern portions of the area, older and topographically higher middle and lower Quaternary deposits attain elevations as high as 78 ft (23.8 m). Local relief is generally less than 16 ft (5 m). The streams and swamps drain centrally from the west, east, and north toward the Cooper River, which flows southward toward the city of Charleston (fig. 1). Although the land close to the Cooper River has fairly steep gradients and is therefore well drained, the lands east of the river do not have an established drainage system other than the system which drained them when they were tidal marshes. As a result, these areas are extremely swampy. The presence of a very permeable limestone aquifer under much of this area (the Goose Creek Limestone) has probably contributed to this swampy topography because of the development in this unit of sinkholes and subterranean drainage rather than a system of surface streams and channels to carry off rainfall. Large tracts of these swampy lands have been used for rice farming. Although the East Branch of the Cooper probably originated as a back-barrier tidal estuary, the West Branch seems to follow a structurally controlled course (section C-C' in the Cordesville quadrangle) that drains southeastward along a trough filled with Oligocene sediment. The loop in the Cooper River opposite Hagan Island in the Kittredge quadrangle has cut a prominent bluff that is unusual for the outer Coastal Plain. This bluff seems to have formed because the sediment filling a buried Pleistocene channel that cuts across the present Cooper at this bend has provided little resistance to the lateral migration of the modern river channel at this point. Elsewhere, the channel of the Cooper River is confined by the tough sediments of the Ashley Formation, which are much more resistant to erosion than the Pleistocene sediments.

In the shallow subsurface, there are fourteen discrete depositional assemblages that record high stands of sea level during the last 44 Ma (fig. 2). Tertiary transgressions extended well to the northwest of this area; the original inland extent of these transgressions has not yet been determined. These deposits are all marine in origin and accumulated during the more recent stages of a prolonged interval of Coastal Plain subsidence during which the Charleston region subsided a total of about 3,000 ft (1,000 m) in Late Cretaceous and early Tertiary times (Gohn and others, 1977). The Charleston area has remained tectonically stable since the Oligocene, but the area to the north has continued to rise (Cape Fear Arch) and the area to the south has continued to subside (Southeast Georgia Embayment). As a result of this regional tectonism, Oligocene and older beds generally occur as wedge-shaped sequences that crop out updip in broad east-west-trending belts which dip and thicken toward the south. Because the Charleston area is near the axis of tilting, successive post-Oligocene transgressions of the Atlantic Ocean have induced extensive reworking of each previously deposited unit. This process has produced a mosaic of small remnants of Miocene to lower Pleistocene units distributed more commonly side by side than in superposition. In contrast, many deposits that formed at the same time farther updip to the north have been almost completely removed, whereas most deposits formed farther downdip to the south have been little disturbed and form nearly continuous sheets.

TERTIARY DEPOSITS

Each Tertiary marine deposit in this area is lithologically distinct and is bounded above and below by disconformities. Basal disconformities commonly are recognized in auger holes by nodular phosphate and (or) glauconite-rich lag deposits that formed during the prolonged interval of nondeposition that each disconformity represents (Weems and others, 1985). Burrows are concentrated in the upper meter of each deposit and are filled with poorly sorted matrix and pebbles from the overlying unit.

The oldest sediments found in the shallow subsurface of these quadrangles are white to pale-yellow limestones which have been named the Santee Limestone (Sloan, 1908). This unit occurs throughout these quadrangles at depth, but only approaches the surface along the northern margin of the map.

Cross Member of the Santee Limestone.—The Santee Limestone was subdivided into two members by Ward and others (1979). The upper Cross member of middle Eocene (Bartonian) age (about 44 Ma) seems to include all of the limestones in this area. The Cross is a generally well lithified white to pale-yellow calcarenite that is sparsely macrofossiliferous. The Cross accumulated on a firm-bottomed but unlithified, open-marine shelf as indicated by its contained invertebrate fauna (Hazel and others, 1977). The Cross is often lithified to a limestone that is difficult or impossible to penetrate with a power auger. At some horizons the Cross is cavernous and may be tapped for a reliable ground water supply.

Cooper Group.—Stratigraphically above the Santee in the shallow subsurface of these quadrangles are soft, impermeable limestones that were once called the "Cooper Marl". Ward and others (1979) referred to this unit as the Cooper Formation and subdivided it into three members, two of which (the Ashley and Parkers Ferry) occur in the map area. Their definitions and names are retained here, but these members have been raised to formation rank and the Cooper has been raised to group rank to conform to the usage of formation and group ranks for rock units farther north in Virginia which are of similar diversity, thickness (around 500 ft or 150 m), and areal extent. Use of the term Cooper as a group has also been advocated by Colquhoun and others (1982).

Parkers Ferry Formation.—This dense, sticky, moderate-yellowish-green to light-blue-green calcilutite formed in a soft-bottomed, open-marine-shelf environment as indicated by the abundant echinoid spines that it contains. A late Eocene (Priabonian) age (about 38 Ma) has been established on the basis of calcareous nannofossil assemblages characteristic of zone NP 20 (Hazel and others, 1977). The Parkers Ferry is sticky and difficult to excavate, but it is easily eroded when exposed to air and water. It is poorly exposed at the base of one river bluff along the East Branch of the Cooper River, but is otherwise not known from outcrop.

Ashley Formation.—The Ashley consists of tough, light-olive-brown, phosphatic and quartzose calcarenite that is only weakly cemented. The abundant marine fauna indicates that it accumulated in an open-marine-shelf environment (Hazel and others, 1977). The presence of sepiolite suggests that a much drier climate existed, at least locally, than at present. Remains of fish, reptiles, birds, and mammals are locally common. A late Oligocene (early Chattian) age (about 30 Ma) has been established on the basis of foraminifers which are

Ladson Formation.—The Ladson sands, clays, and clayey sands present in the type section (Malde, 1959) underlie the upper Talbot terrace northwest of the Bethera scarp (Colquhoun, 1974). This unit is equivalent to unit Q4 of McCartan and others (1984). The present elevation of the top of the lagoonal deposits included within this unit indicates that the Ladson was deposited at a time when sea level in the Charleston area stood about 50 ft (15 m) above its present level relative to the land. At the time of maximum transgression, the shoreline was marked by an elongate barrier island (the Bethera barrier) which now forms the sand deposits (unit Qls) preserved in the northeastern portion of the map area. The crest of this feature is at an elevation of about 60–65 ft (18–19 m) above sea level, except where it overlies deep filled Pleistocene channels. In these places, elevations are anomalously low because the compaction of the underlying thick Pleistocene deposits has produced exceptional settling of the land. Whitten Bay, in the Bethera quadrangle, occupies one of these low-lying areas. Alligator Creek, in the same quadrangle, has a slightly different origin. There a modern stream has reoccupied the course of an old filled channel that produced a low-lying area in the Bethera barrier. Immediately preceding the formation of the Bethera barrier, the ancestral Santee River was apparently entrenched in a channel that trended diagonally across the Bethera quadrangle from the north border southeastward to the east border. This channel, subsequently buried by Ladson sediments, contains thick, coarse-grained, feldspathic pebbly quartz sands (Qlr) at its base. Near the time of maximum transgression of the shoreline during deposition of the Ladson formation, the Santee built its level above its filled valley and migrated southward to a course roughly following the present Cooper River valley. There it spread clayey, coarse-grained sand and feldspathic gravels (Qlc) across its delta front and adjacent lagoons in the north-central and western portions of the map area. By the end of Ladson time, however, the ancestral Santee must have migrated back to the north, where it became entrenched in its present channel north of this map area when sea level dropped again at the end of Ladson time (see fig. 1). Back-barrier clays of the Ladson Formation in the Stallsville quadrangle have normal magnetic polarities (Liddicoat and others, 1981), so they must be younger than 730 ka. Corals from the next younger unit, the Ten Mile Hill beds, have yielded U/Th ratios which indicate that those beds are 200 to 240 ka in age. Therefore, the age of the Ladson must be between 240 and 730 ka. The Ladson Formation may be equivalent to the Canepatch Formation of DuBar (1971), which has yielded U/Th ratios suggesting an age of about 450 ka in the vicinity of Myrtle Beach, S. C. (Cronin and others, 1981). Because the name Ladson is older, it takes priority over the name Canepatch. The Ladson is poorly consolidated, easily excavated, and readily eroded. Clay-rich intervals may be quite sticky.

Ten Mile Hill beds.—The clays and clayey sands here included in the Ten Mile Hill beds were deposited in a lagoonal environment that existed landward of a barrier beach, the sands of which now constitute Ten Mile Hill. These lagoonal deposits formerly were included in the Ladson Formation by Malde (1959) because they formed in similar environments, but they are mapped separately in this report because they record a younger transgression and regression of the sea than that recorded by the beds forming the Ladson type section. Malde defines the "sands on Ten Mile Hill" (a term previously used by Sloan, 1908), but not the associated lagoonal deposits, as a lithologic unit younger than the Ladson Formation. The name is modified here to "Ten Mile Hill beds" and is expanded to include the deposits in the back-barrier and shallow-shelf environments that existed adjacent to the barrier-beach that once occupied the present position of Ten Mile Hill. The Ten Mile Hill beds, as here defined, underlie the lower Talbot terrace southeast of the Bethera scarp (Colquhoun, 1974) and are equivalent to unit Q3 of McCartan and others (1984). The Ten Mile Hill beds were deposited at a time when sea level in the Charleston area stood about 35 ft (11 m) above its present level relative to the land as indicated by the present elevation of the top of the lagoonal deposits associated with this unit. The Cainhoy barrier system, which is composed of sands of the Ten Mile Hill beds, is present only in the southeastern corner of the present map area (Qts) and marks the southeastward margin of the outcrop belt of these deposits. The highest elevation of this barrier is about 50 ft (15 m) above sea level. Northwest of this barrier, clay-rich Ten Mile Hill deposits (Qtc) formed in back-barrier to estuarine environments. The coarse, angular fluvial sands, which are such a distinctive component of the Ladson back-barrier deposits, are absent from this unit except where locally reworked into the basal few feet. Corals recovered by the authors from marine deposits of the Ten Mile Hill beds in the Ravenel and Johns Island quadrangles yielded U/Th ratios which indicate that the unit accumulated between 200 and 240 ka ago (Cronin and others, 1981; McCartan and others, 1982). This age corresponds to marine oxygen-isotope Stage 7 of Shackleton and Opdyke (1973). The Ten Mile Hill beds are poorly consolidated, easily excavated, and readily eroded. Clay-rich intervals may be quite sticky. The Ten Mile Hill beds, especially the well-sorted sands around Ten Mile Hill, underwent extensive liquefaction during the 1886 Charleston earthquake.

Wando Formation.—The Wando Formation is defined by McCartan and others (1980) as beds of sand, clayey sand, and clay which underlie the Pamlico and Princess Anne Terraces of Colquhoun (1974). This unit was mapped as unit Q2 by McCartan and others (1984). The Wando was deposited when sea level in the Charleston area stood about 25 ft (7.5 m) (as indicated by the Pamlico terrace) and 15 ft (4.5 m) (as indicated by the Princess Anne terrace) above its present level relative to the land. In the map area, Wando deposits are known only from the lower high-sea-level stand. The sea did not transgress inland as far as this area, but it did back water into an extensive system of estuaries along the Cooper River. These estuaries then became partly filled with clay and clayey sand (Qwc) to elevations as high as 15 ft (4.5 m) above present sea level. The Wando deposits beneath Biggin Swamp are probably the source of the mammoth and mastodon remains that were uncovered in the eighteenth century during the construction of the Santee-Cooper Canal (Drayton, 1802; Hay, 1923). Corals from marine beds of the Wando in the Cainhoy, Fort Moultrie, and Johns Island quadrangles have yielded U/Th ratios which indicate that this unit correlates with the Sangamon interglacial stage of 130 to 70 ka ago (Cronin and others, 1981; McCartan and others, 1982) and marine oxygen-isotope Stage 5 of Shackleton and Opdyke (1973). The Wando is poorly consolidated, easily excavated, and readily eroded. Clay-rich intervals may be quite sticky. Wando sand beds underwent extensive liquefaction to the south and west of this area during the 1886 Charleston earthquake (Dutton, 1889), but liquefaction features have not yet been found in this map area.

Holocene deposits.—Materials that have accumulated within the last 10 ka are not formally named. Some of these deposits (Qhec) formed in tidal marshes associated with estuaries that extended up the Cooper River estuary from the Silver Bluff Terrace of Colquhoun (1974), while others presently are forming in and around the modern Cooper River estuary (Qht). Round to ellipsoidal depressions (the largest of which could be considered "Carolina bays") commonly are filled with peat and muck deposits which date from the Wisconsinan

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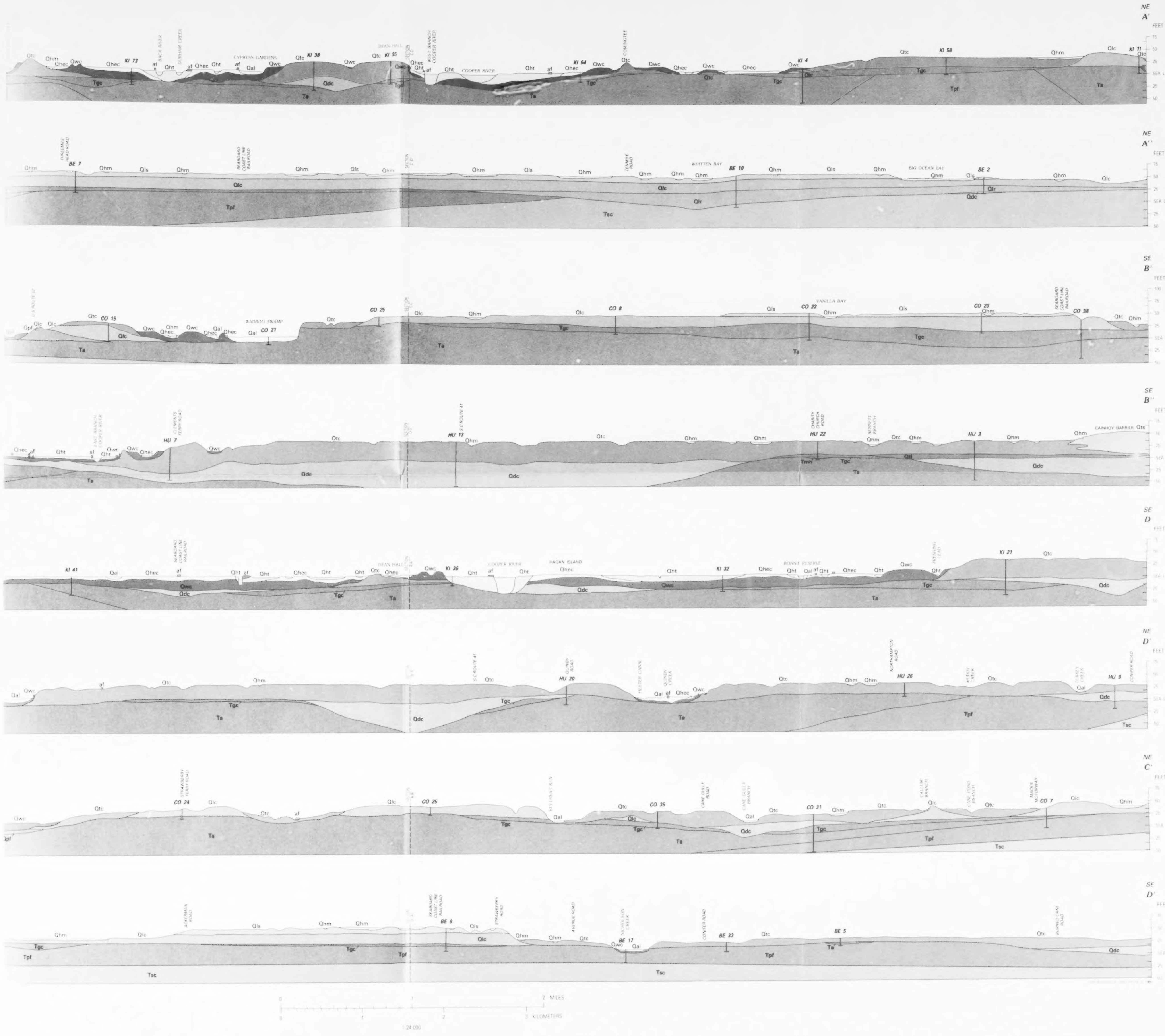

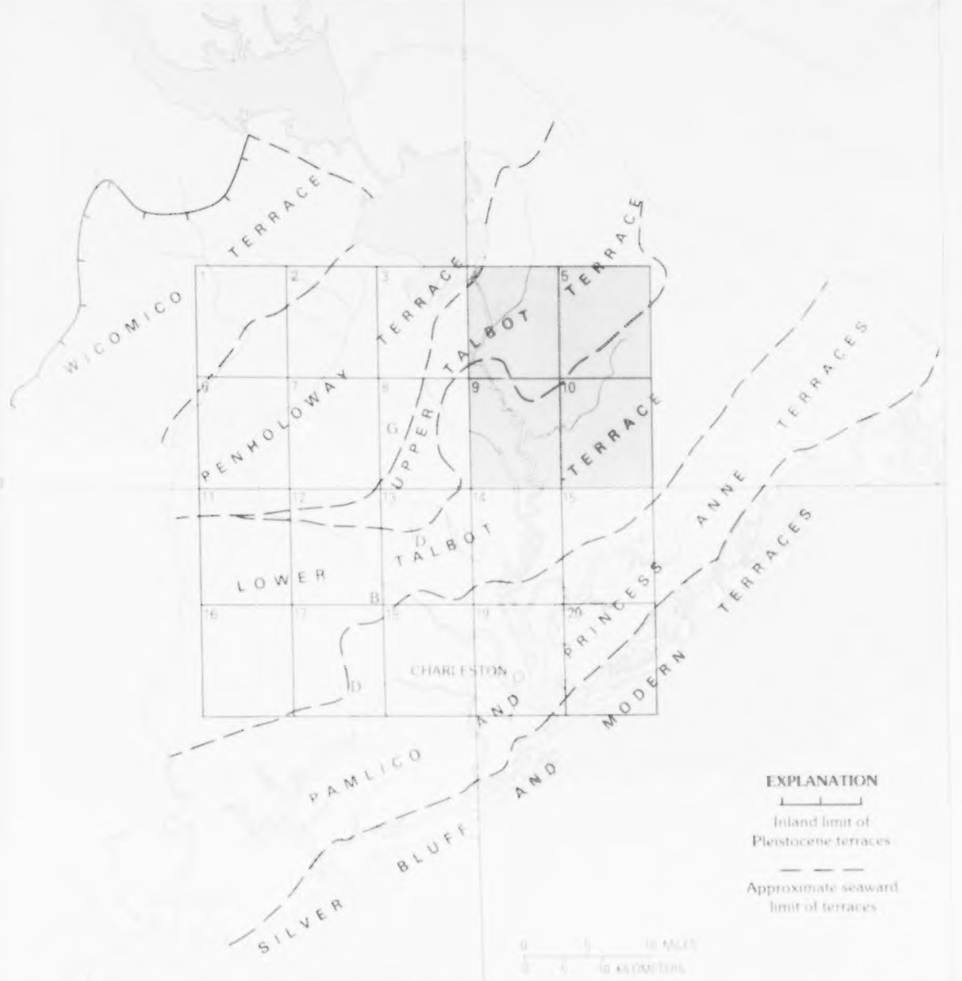

FIGURE 1.—Map of Pleistocene terraces, estimates of epicenters for earthquake of August 31, 1886, and index of 7.5' quadrangles covering study area. B–Estimate of epicenter (Bollinger, 1977). D–Estimate of two epicenters (Dutton, 1889). G–Estimate of epicenter (Gibbes and others, 1887). Terrace nomenclature established by Cooke (1936) and Colquhoun (1974)

INDEX SHOWING QUADRANGLE LOCATIONS

1. Pringletown
2. Summerville N.W.
3. Moncks Corner
4. Cordesville
5. Bethera
6. Ridgeville
7. Summerville
8. Mount Holly
9. Kittredge
10. Huger
11. Clubhouse Crossroads
12. Stallsville
13. Ladson
14. North Charleston
15. Cainhoy
16. [illegible]
17. Ravenel
18. Johns Island
19. Charleston
20. Fort Moultrie

ENVIRONMENT

HUMAN INFLUENCE	FRESH WATER MARSH	FLUVIAL	ESTUARINE TO BACKBARRIER	BARRIER ISLAND	SHALLOW SHELF	MIDDLE SHELF	AGE
af	Qhm	Qal	Qht				Holocene
			Qhec				
			Qwc				
			Qtc	Qts	Qtf		
		Qlr	Qlc	Qls			Pleistocene
			Qpc	Qps	Qpf		
			Qdc				
					Qwwf		
					Tgc		Pliocene
			Tmh				Miocene
			Tm				Oligocene
						Ta	
						Tpf	Eocene
						Tsc	

FIGURE 2.—Depositional environments in which sediments of map units accumulated

ation.—The Ladson sands, clays, and clayey sands present in the type section (Malde, 1959) Talbot terrace northwest of the Bethera scarp (Colquhoun, 1974). This unit is equivalent rtan and others (1984). The present elevation of the top of the lagoonal deposits included icates that the Ladson was deposited at a time when sea level in the Charleston area stood above its present level relative to the land. At the time of maximum transgression, the by an elongate barrier island (the Bethera barrier) which now forms the sand deposits of the northeastern portion of the map area. The crest of this feature is at an elevation 19 m) above sea level, except where it overlies deep filled Pleistocene channels. In these anomalously low because the compaction of the underlying thick Pleistocene deposits has settling of the land. Whitten Bay, in the Bethera quadrangle, occupies one of these low- Creek, in the same quadrangle, has a slightly different origin. There a modern stream has of an old filled channel that produced a low-lying area in the Bethera barrier. Immediately of the Bethera barrier, the ancestral Santee River was apparently entrenched in a diagonally across the Bethera quadrangle from the north border southeastward to the east subsequently buried by Ladson sediments, contains thick, coarse-grained, feldspathic (Qlr) at its base. Near the time of maximum transgression of the shoreline during deposition ation, the Santee built its level above its filled valley and migrated southward to a course present Cooper River valley. There it spread clayey, coarse-grained sand and feldspathic its delta front and adjacent lagoons in the north-central and western portions of the map Ladson time, however, the ancestral Santee must have migrated back to the north, where in its present channel north of this map area when sea level dropped again at the end fig. 1). Back-barrier clays of the Ladson Formation in the Stallsville quadrangle have normal Liddicoat and others, 1981), so they must be younger than 730 ka. Corals from the next Mile Hill beds, have yielded U/Th ratios which indicate that those beds are 200 to 240 the age of the Ladson must be between 240 and 730 ka. The Ladson Formation may Canepatch Formation of DuBar (1971), which has yielded U/Th ratios suggesting an age vicinity of Myrtle Beach, S. C. (Cronin and others, 1981). Because the name Ladson over the name Canepatch. The Ladson is poorly consolidated, easily excavated, and intervals may be quite sticky.

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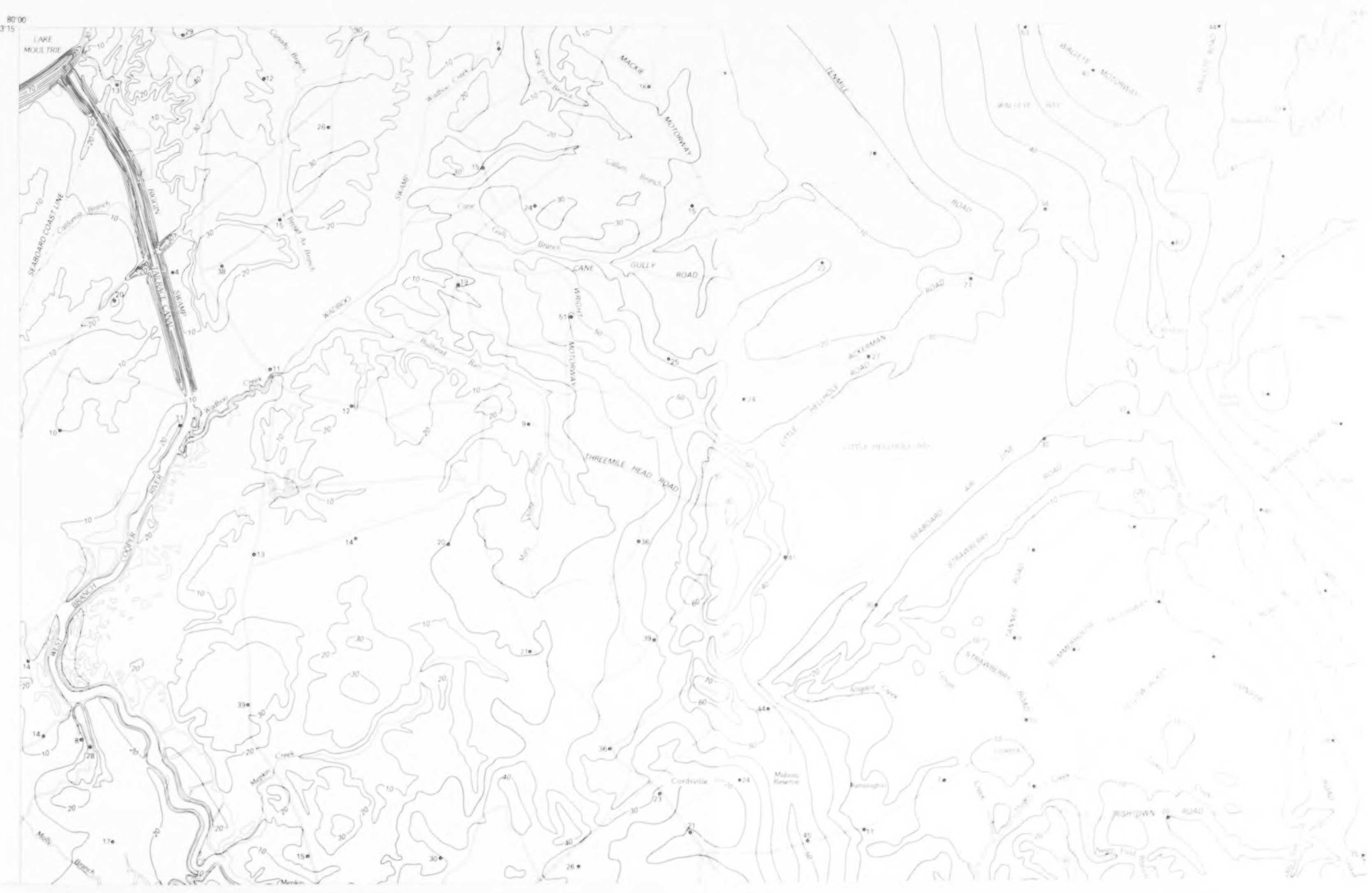

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INTRODUCTION

The Bethera, Cordesville, Huger, and Kittredge quadrangles, an area of about 200 sq mi (650 sq km), are located in the outer Atlantic Coastal Plain about midway between the Cape Fear Arch (to the northeast) and the Southeast Georgia Embayment (to the southwest). Marine, marginal-marine, and fluvial-estuarine sediments, ranging in age from middle Eocene to Holocene, crop out or are present just beneath the land surface in these quadrangles. The area is generally low and flat, especially where underlain by upper Quaternary deposits along the Cooper River and its tributaries. In the northwestern and northeastern portions of the area, older and topographically higher middle and lower Quaternary deposits attain elevations as high as 78 ft (23.8 m). Local relief is generally less than 16 ft (5 m). The streams and swamps drain centrally from the west, east, and north toward the Cooper River, which flows southward toward the city of Charleston (fig. 1). Although the land close to the Cooper River has fairly steep gradients and is therefore well drained, the lands east of the river do not have an established drainage system other than the system which drained them when they were tidal marshes. As a result, these areas are extremely swampy. The presence of a very permeable limestone aquifer under much of this area (the Goose Creek Limestone) has probably contributed to this swampy topography because of the development in this unit of sinkholes and subterranean drainage rather than a system of surface streams and channels to carry off rainfall. Large tracts of these swampy lands have been used for rice farming. Although the East Branch of the Cooper probably originated as a back-barrier tidal estuary, the West Branch seems to follow a structurally controlled course (section **C-C′** in the Cordesville quadrangle) that drains southeastward along a trough filled with Oligocene sediment. The loop in the Cooper River opposite Hagan Island in the Kittredge quadrangle has cut a prominent bluff that is unusual for the outer Coastal Plain. This bluff seems to have formed because the sediment filling a buried Pleistocene channel that cuts across the present Cooper at this bend has provided little resistance to the lateral migration of the modern river channel at this point. Elsewhere, the channel of the Cooper River is confined by the tough sediments of the Ashley Formation, which are much more resistant to erosion than the Pleistocene sediments.

In the shallow subsurface, there are fourteen discrete depositional assemblages that record high stands of sea level during the last 44 Ma (fig. 2). Tertiary transgressions extended well to the northwest of this area; the original inland extent of these transgressions has not yet been determined. These deposits are all marine in origin and accumulated during the more recent stages of a prolonged interval of Coastal Plain subsidence during which the Charleston region subsided a total of about 3,000 ft (1,000 m) in Late Cretaceous and early Tertiary times (Gohn and others, 1977). The Charleston area has remained tectonically stable since the Oligocene, but the area to the north has continued to rise (Cape Fear Arch) and the area to the south has continued to subside (Southeast Georgia Embayment). As a result of this regional tectonism, Oligocene and older beds generally occur as wedge-shaped sequences that crop out updip in broad east-west-trending belts which dip and thicken toward the south. Because the Charleston area is near the axis of tilting, successive post-Oligocene transgressions of the Atlantic Ocean have induced extensive reworking of each previously deposited unit. This process has produced a mosaic of small remnants of Miocene to lower Pleistocene units distributed more commonly side by side than in superposition. In contrast, many deposits that formed at the same time farther updip to the north have been almost completely removed, whereas most deposits formed farther downdip to the south have been little disturbed and form nearly continuous sheets.

TERTIARY DEPOSITS

Each Tertiary marine deposit in this area is lithologically distinct and is bounded above and below by disconformities. Basal disconformities commonly are recognized in auger holes by nodular phosphate and (or) glauconite-rich lag deposits that formed during the prolonged interval of nondeposition that each disconformity represents (Weems and others, 1985). Burrows are concentrated in the upper meter of each deposit and are filled with poorly sorted matrix and pebbles from the overlying unit.

The oldest sediments found in the shallow subsurface of these quadrangles are white to pale-yellow limestones which have been named the Santee Limestone (Sloan, 1908). This unit occurs throughout these quadrangles at depth, but only approaches the surface along the northern margin of the map.

Cross Member of the Santee Limestone.—The Santee Limestone was subdivided into two members by Ward and others (1979). The upper Cross member of middle Eocene (Bartonian) age (about 44 Ma) seems to include all of the limestones in this area. The Cross is a generally well lithified white to pale-yellow calcarenite that is sparsely macrofossiliferous. The Cross accumulated on a firm-bottomed but unlithified, open-marine shelf as indicated by its contained invertebrate fauna (Hazel and others, 1977). The Cross is often lithified to a limestone that is difficult or impossible to penetrate with a power auger. At some horizons the Cross is cavernous and may be tapped for a reliable ground water supply.

Cooper Group.—Stratigraphically above the Santee in the shallow subsurface of these quadrangles are soft, impermeable limestones that were once called the "Cooper Marl." Ward and others (1979) referred to this unit as the Cooper Formation and subdivided it into three members, two of which (the Ashley and Parkers Ferry) occur in the map area. Their definitions and names are retained here, but these members have been raised to formation rank and the Cooper has been raised to group rank to conform to the usage of formation and group ranks for rock units farther north in Virginia which are of similar diversity, thickness (around 500 ft or 150 m), and areal extent. Use of the term Cooper as a group has also been advocated by Colquhoun and others (1982).

Parkers Ferry Formation.—This dense, sticky, moderate-yellowish-green to light-blue-green calcilutite formed in a soft-bottomed, open-marine-shelf environment as indicated by the abundant echinoid spines that it contains. A late Eocene (Priabonian) age (about 38 Ma) has been established on the basis of calcareous nannofossil assemblages characteristic of zone NP 20 (Hazel and others, 1977). The Parkers Ferry is sticky and difficult to excavate, but it is easily eroded when exposed to air and water. It is poorly exposed at the base of one river bluff along the East Branch of the Cooper River, but is otherwise not known from outcrop.

Ashley Formation.—The Ashley consists of tough, light-olive-brown, phosphatic and quartzose calcarenite that is only weakly cemented. The abundant marine fauna indicates that it accumulated in an open-marine-shelf environment (Hazel and others, 1977). The presence of sepiolite suggests that a much drier climate existed, at least locally, than at present. Remains of fish, reptiles, birds, and mammals are locally common. A late Oligocene (early Chattian) age (about 30 Ma) has been established on the basis of foraminifers which are characteristic of zones P20–21 and calcareous nannofossil assemblages which are characteristic of zone NP 24 (Hazel and others, 1977). The Ashley is the only unit in this area that readily crops out naturally, in part because it tends to harden upon exposure to air. The unit crops out intermittently along the West Branch of the Cooper River and at one bluff along Wadboo Creek. Man-made cuts in the Ashley resist erosion and may persist for a few years before becoming overgrown.

Chandler Bridge Formation.—The medium-gray to dusky-green quartz and phosphate sands of the Chandler Bridge accumulated in lagoonal to shallow marine environments of deposition, as indicated by the admixture of marine vertebrate and terrestrial plant remains in this unit (Sanders and others, 1982). The flora suggests that deposition occurred in a warm, temperate climate comparable to the present. Vertebrate remains are common, diverse, and well preserved. A late Oligocene (middle Chattian) age (about 28 Ma) is inferred from the odontocete whale fauna collected from this unit and stored at the Charleston Museum. The Chandler Bridge is soft and erodes readily. For this reason it has been extensively stripped by erosion and persists mostly in thin patches in low areas overlying the Ashley Formation. It has been penetrated in the subsurface of these quadrangles only along the western margin of the map area (localities ***CO–10***, ***KI–62***, and ***KI–75***).

Edisto Formation.—The light-yellowish-brown, shelly, quartzose calcarenites of the latest Oligocene and (or) earliest Miocene Edisto Formation (about 23 Ma) were considered by Sloan (1908) to be the parent lithology for the "rock phosphate" which was once extensively mined in the Charleston area. This view was challenged by Malde (1959), who thought that the Ashley Formation was a more likely source for this material. Recently, dinoflagellates were found in a sample of the phosphate rock. The contained flora in the phosphate rock includes species which appear later than Ashley or Chandler Bridge time, but all of the species are closely comparable to those known elsewhere from the flora of the Edisto and Marks Head Formations (Lucy E. Edwards, written commun., 1985). Therefore, Sloan's view is accepted here. The Edisto probably forms the rock phosphate present at Rock Hole in the Bethera quadrangle (see section on economic geology and water resources) and the phosphate-rich lag deposits which once were dredged from the bottom of the East Branch of the Cooper River (Penrose, 1888). This formation was not penetrated in normal stratigraphic sequence anywhere in these quadrangles, and it is suspected that it only occurs as reworked blocks in the basal lag deposits of younger units.

Marks Head Formation.—The Marks Head Formation, as used by Abbott and Huddlestun (1980), was penetrated in only one drill hole within the confines of this map (***HU–22***). The unit occurs sporadically as outliers to the west in the Mount Holly quadrangle (Weems and Lemon, 1984), but it does not form a continuous outcrop belt until much farther south (downdip) in the meizoseismal region, specifically along the southern borders of the Fort Moultrie, Charleston, Johns Island, Ravenel, and Osborn quadrangles (see fig. 1). The Marks Head consists of olive-gray to moderate-olive-brown quartz-phosphate sands and attapulgite-rich clays. The presence of attapulgite suggests that this unit accumulated in shallow, brackish-water coastal lagoons (Weaver and Beck, 1982). Although the Marks Head in the Charleston area usually only contains dinoflagellates as presently preserved, farther south it has yielded foraminifera which suggest it is early Miocene (Burdigalian) in age (about 18 Ma) (Abbott and Huddlestun, 1980).

Goose Creek Limestone.—The white to very pale-orange quartzose and phosphatic calcarenites of the Goose Creek were deposited in an open-shelf, shallow-marine environment that received very little clastic influx from the land (Weems and others, 1982). Vertebrate remains are locally abundant, as are shells of pectinids such as *Amusium mortoni*, *Argopecten eboreus*, and *Pecten hemicyclica*. Only calcitic shells have survived; aragonitic shells are leached out, leaving only molds and casts. The Goose Creek is early to middle Pliocene in age (between 3 and 5 Ma) as indicated by the occurrence of the shark *Carcharodon carcharias* together with the calcareous nannoplankton species *Reticulofenestra pseudombilica* (Gartner, 1967) and *Sphenolithus abies* Deflandre, 1954. The Goose Creek normally is soft and easily excavated, but it can be calcite-cemented locally into indurated lumps. Ground water flows freely through this unit, and locally it is known as "the water sands."

QUATERNARY DEPOSITS

Quaternary deposits form terrace complexes which represent partially filled back-barriers, barrier islands, and shallow-ocean floor deposits (fig. 2). These deposits formed during interglacial ages, during which sea level was high due to extensive melting of the polar icecaps. They are very similar to the deposits forming along the Atlantic coastline today. This similarity suggests that each barrier-island deposit represents the position of the Atlantic shoreline at the time it was formed.

Regionally, there are five Pleistocene terrace complexes. Their ages have been established by using biostratigraphic methods, uranium-disequilibrium-series dates obtained from corals, and observations of the relative degree of weathering of clay and heavy minerals in each unit (McCartan and others, 1984). The ages and stratigraphic relationships indicate that the terrace deposits record successive transgressive and regressive ocean shoreline movements caused by changes in sea level. Presumably, these changes in sea level in turn were the result of the cyclical retreats and advances of the continental ice sheets during the Pleistocene. Normally, on tectonically stable coasts, littoral erosion associated with successive high-sea-level stands remove nearly all deposits of previous high-sea-level stands. The preserved depositional record of many of the earlier Quaternary sea-level oscillations in the Charleston region attests to broad crustal uplift that has occurred in the Charleston region throughout the Quaternary (Cooke, 1936). This uplift has carried older beach complexes upward, out of reach of later littoral erosion during subsequent high-sea-level stands. Present altitudes of successive deposits indicate that the average rate of this uplift has been 0.7 in. (1.8 cm)/1,000 years (Cronin and others, 1981). Although barrier and back-barrier deposits are preserved, each succeeding transgression largely reworked the shallow shelf deposits seaward of each immediately older barrier ridge. Because of this, younger beach-ridge and lagoonal deposits lie immediately seaward of and at slightly lower altitudes than the next older coastal deposits. Sediments of younger units also fill the bottoms of what had been water-filled estuaries and lagoons during older transgressions (see cross sections ***B-B′*** in the Cordesville and Huger quadrangles and ***C′-D′*** in the Bethera quadrangle).

The base of the various Quaternary transgressive-regressive sediment sequences was located from shallow auger holes, excavations, and outcrops numbered on the map. These holes and localities serve as control for the structure contours drawn on the base of these Quaternary units on this map and for the smaller scale isopach map of the same area (fig. 3). This contoured horizon is of variable age, but it separates the unconsolidated Quaternary deposits from underlying well-compacted to partially lithified Tertiary deposits.

Quaternary map units used in this report correspond to numbered chronolithologic units of the South Carolina Coastal Plain of McCartan and others (1984). Each lithologic sequence is most commonly found beneath an associated recognizable terrace surface. Each lithologic sequence is not found beneath terraces at elevations above that of its normally associated terrace surface, but sporadic outliers are occasionally penetrated when drilling through the deposits immediately beneath terraces which lie at lower elevations. Colquhoun (1974) has applied the names shown in figure 1 to the geomorphic terrace features associated with each lithologic sequence. Stratigraphic names are assigned herein to each associated lithologic unit because 1) each lithologic sequence is bounded both above and below by a recognizable unconformity, either in the form of a detrital lag deposit or an actively eroding upper surface, 2) the local and regional stratigraphic relationships have been worked out from extensive new subsurface data, 3) biostratigraphic control for the lithologically subdivided units is now available, and 4) radiometric ages determined for these units show they vary widely in age. Parts of the Ten Mile Hill beds are included in the Ladson Formation by Malde (1959), but they are mapped separately in this report. Although these units are somewhat similar in lithology (Lemon, 1979), they are easily differentiated by their positions below different recognizable terrace surfaces (Colquhoun, 1974).

Within each mapped Quaternary rock unit, three facies based on association of lithology, texture, and fossils are readily recognized and mapped separately. They correspond to fluvial-estuary-back-barrier (c), barrier-island (s), and open-marine-shelf (f) depositional environments (fig. 2; l, b, and o respectively in McCartan and others, 1984). These facies usually grade into each other over a vertical distance of 1–3 ft (1 m), although in places where barrier sands have migrated over back-barrier clays or where estuary channels have produced cut-and-fill structures, the contact may be quite sharp. Usually, coarse-grained, pebbly lag beds only occur at the base of each interglacial facies complex and not between facies. The thickness of the Quaternary facies units ranges from 0 to 110 ft (0 to 33 m) (fig. 3), and is dependent on local variations in spatial relationships between paleochannels, barrier-island morphology, and postdepositional erosion.

Waccamaw Formation(?).—Several drill holes in the Cordesville, Bethera, and Huger quadrangles penetrated quartz sands containing numerous fragments of aragonitic mollusks. Late Pliocene to early Pleistocene ostracodes (open marine types) were found in a sample from one of these drill holes (***HU–14***) (Thomas M. Cronin, written commun., 1984). Because this fauna and lithology are compatible with those described from the Waccamaw Formation near Myrtle Beach, these sediments are tentatively assigned to that unit. The Waccamaw(?) contrasts with the overlying lower Pleistocene Penholoway Formation in that the fossil fauna in the Waccamaw(?) is considerably more diverse and its sediments considerably more calcareous than any seen so far from the Penholoway. The abundance of aragonitic mollusk fragments in the Waccamaw(?) contrasts sharply with the calcitic sediment of the underlying Pliocene Goose Creek Formation near Charleston and the Pliocene Bear Bluff Formation near Myrtle Beach, S. C. The Waccamaw(?) was found near the surface only in the Bethera quadrangle, and in that limited area it was projected onto the surface map. In the Cordesville and Huger quadrangles, it is buried more deeply and is shown in some of the cross sections and auger hole logs.

Daniel Island beds.—This name is applied informally to a subsurface unit composed of layers of dark-bluish-gray to dark-gray clay, mud, and sandy clay. These beds represent the first deposits of an extensive paleo-estuary system which has been traced from Daniel Island in the Charleston quadrangle northward to the Kittredge, Bethera, and Cordesville quadrangles and westward to the Ravenel quadrangle. Ostracodes in these deposits are early Pleistocene (Sharon Lyons, written commun., 1982), and the assemblages include only species tolerant of brackish water, even in the vicinity of Daniel Island. To the north, the ostracodes indicate a fresher water environment of deposition and peat becomes more common. This evidence suggests that at the time of deposition of these beds, the shoreline lay at approximately the same position as the present shoreline. Any associated terrace and barrier deposits which may have formed were probably destroyed by erosion associated with middle and late Pleistocene transgressions which extended well to the west of this area. This unit has been preserved only in deeply cut estuaries that were not completely scoured out during the later transgressions. Numerous drill holes have penetrated these beds in the subsurface of this map area, but most beds are concentrated in the deep paleochannel that runs from the eastern side of the Cordesville quadrangle southward to the southeastern corner of the Huger quadrangle. This unit has not been dated more closely than early Pleistocene and is tentatively assumed to be intermediate in age between the Waccamaw Formation and the Penholoway Formation (units Q6 and Q5 of McCartan and others, 1984) because this is the longest time gap present within the local Pleistocene section.

Penholoway Formation.—The Penholoway Formation, equivalent to unit Q5 of McCartan and others (1984), consists of sand, clayey sand, and clay deposited in shallow-marine to marginal-marine environments. Within the map area, the Penholoway is exposed only in the northwestern corner of the Cordesville quadrangle where the Summerville barrier beach deposit of Colquhoun (1974) is present. This feature marked the shoreline of the Atlantic Ocean at the time of maximum transgression when it was formed, and the present elevation of the top of the back-barrier lagoonal deposits behind this barrier indicate that the Penholoway was deposited at a time when sea level in the Charleston area stood about 75 ft (23 m) above its present level relative to the land. Back-barrier clay beds beneath the Penholoway terrace have reversed magnetic polarities (Liddicoat and others, 1981), except where recently weathered. This polarity indicates that the Penholoway is older than 730 ka (0.73 Ma). Additionally, a coral from the Penholoway marine beds in the Stallsville quadrangle yielded a U/Th age of over 700 ka (Szabo, 1985). The basal marine beds of the Penholoway in the Summerville quadrangle also have yielded sparse calcareous nannofossils, none of which suggest an age older than the upper part of the Quaternary Zone NN19 of Martini (1971), or no older than 970 ka (Laurel Bybell, written commun., 1984). The Penholoway in this map area is poorly consolidated, easily excavated, and readily eroded. Biggin Swamp, which constitutes the upper reaches of the West Branch of the Cooper River, appears to occupy a valley previously occupied by an old river channel which was filled and buried by Penholoway marine sediments during the Penholoway transgression. Because this old channel was filled only by loose sands, the small modern stream flowing through this swamp was able to excavate a wide, flat valley much larger than would be expected for such a small stream.

Ladson Formation.—The Ladson sands, clays, and clayey sands present in the type section (Malde, 1959) underlie the upper Talbot terrace northwest of the Bethera scarp (Colquhoun, 1974). This unit is equivalent to unit Q4 of McCartan and others (1984). The present elevation of the top of the lagoonal deposits included within this unit indicates that the Ladson was deposited at a time when sea level in the Charleston area stood about 50 ft (15 m) above its present level relative to the land. At the time of maximum transgression, the shoreline was marked by an elongate barrier island (the Bethera barrier) which now forms the sand deposits (unit **Qls**) preserved in the northeastern portion of the map area. The crest of this feature is at an elevation of about 60–65 ft (18–19 m) above sea level, except where it overlies deep filled Pleistocene channels. In these places, elevations are anomalously low because the compaction of the underlying thick Pleistocene deposits has produced exceptional settling of the land. Whitten Bay, in the Bethera quadrangle, occupies one of these low-lying areas. Alligator Creek, in the same quadrangle, has a slightly different origin. There a modern stream has reoccupied the course of an old filled channel that produced a low-lying area in the Bethera barrier. Immediately preceding the formation of the Bethera barrier, the ancestral Santee River was apparently entrenched in a channel that trended diagonally across the Bethera quadrangle from the north border southeastward to the east border. This channel, subsequently buried by Ladson sediments, contains thick, coarse-grained, feldspathic pebbly quartz sands (**Qlr**) at its base. Near the time of maximum transgression of the shoreline during deposition of the Ladson formation, the Santee built its level above its filled valley and migrated southward to a course roughly following the present Cooper River valley. There it spread clayey, coarse-grained sand and feldspathic gravels (**Qlc**) across its delta front and adjacent lagoons in the north-central and western portions of the map area. By the end of Ladson time, however, the ancestral Santee must have migrated back to the north, where it became entrenched in its present channel north of this map area when sea level dropped again at the end of Ladson time (see fig. 1). Back-barrier clays of the Ladson Formation in the Stallsville quadrangle have normal magnetic polarities (Liddicoat and others, 1981), so they must be younger than 730 ka. Corals from the next younger unit, the Ten Mile Hill beds, have yielded U/Th ratios which indicate that those beds are 200 to 240 ka in age. Therefore, the age of the Ladson must be between 240 and 730 ka. The Ladson Formation may be equivalent to the Canepatch Formation of DuBar (1971), which has yielded U/Th ratios suggesting an age of about 450 ka in the vicinity of Myrtle Beach, S. C. (Cronin and others, 1981). Because the name Ladson is older, it takes priority over the name Canepatch. The Ladson is poorly consolidated, easily excavated, and readily eroded. Clay-rich intervals may be quite sticky.

Ten Mile Hill beds.—The clays and clayey sands here included in the Ten Mile Hill beds were deposited in a lagoonal environment that existed landward of a barrier beach, the sands of which now constitute Ten Mile Hill. These lagoonal deposits formerly were included in the Ladson Formation by Malde (1959) because they formed in similar environments, but they are mapped separately in this report because they record a younger transgression and regression of the sea than that recorded by the beds forming the Ladson type section. Malde defines the "sands on Ten Mile Hill" (a term previously used by Sloan, 1908), but not the associated lagoonal deposits, as a lithologic unit younger than the Ladson Formation. The name is modified here to "Ten Mile Hill beds" and is expanded to include the deposits in the back-barrier and shallow-shelf environments that existed adjacent to the barrier-beach that once occupied the present position of Ten Mile Hill. The Ten Mile Hill beds, as here defined, underlie the lower Talbot terrace southeast of the Bethera scarp (Colquhoun, 1974) and are equivalent to unit Q3 of McCartan and others (1984). The Ten Mile Hill beds were deposited at a time when sea level in the Charleston area stood about 35 ft (11 m) above its present level relative to the land as indicated by the present elevation of the top of the lagoonal deposits associated with this unit. The Cainhoy barrier system, which is composed of sands of the Ten Mile Hill beds, is present only in the southeastern corner of the present map area (**Qts**) and marks the southeastward margin of the outcrop belt of these deposits. The highest elevation of this barrier is about 50 ft (15 m) above sea level. Northwest of this barrier, clay-rich Ten Mile Hill deposits (**Qtc**) formed in back-barrier to estuarine environments. The coarse, angular fluvial sands, which are such a distinctive component of the Ladson back-barrier deposits, are absent from this unit except where locally reworked into the basal few feet. Corals recovered by the authors from marine deposits of the Ten Mile Hill beds in the Ravenel and Johns Island quadrangles yielded U/Th ratios which indicate that the unit accumulated between 200 and 240 ka ago (Cronin and others, 1981; McCartan and others, 1982). This age corresponds to marine oxygen-isotope Stage 7 of Shackleton and Opdyke (1973). The Ten Mile Hill beds are poorly consolidated, easily excavated, and readily eroded. Clay-rich intervals may be quite sticky. The Ten Mile Hill beds, especially the well-sorted sands around Ten Mile Hill, underwent extensive liquefaction during the 1886 Charleston earthquake.

Wando Formation.—The Wando Formation is defined by McCartan and others (1980) as beds of sand, clayey sand, and clay which underlie the Pamlico and Princess Anne Terraces of Colquhoun (1974). This unit was mapped as unit Q2 by McCartan and others (1984). The Wando was deposited when sea level in the Charleston area stood about 25 ft (7.5 m) (as indicated by the Pamlico terrace) and 15 ft (4.5 m) (as indicated by the Princess Anne terrace) above its present level relative to the land. In the map area, Wando deposits are known only from the lower high-sea-level stand. The sea did not transgress inland as far as this area, but it did back water into an extensive system of estuaries along the Cooper River. These estuaries then became partly filled with clay and clayey sand (**Qwc**) to elevations as high as 15 ft (4.5 m) above present sea level. The Wando deposits beneath Biggin Swamp are probably the source of the mammoth and mastodon remains that were uncovered in the eighteenth century during the construction of the Santee-Cooper Canal (Drayton, 1802; Hay, 1923). Corals from marine beds of the Wando in the Cainhoy, Fort Moultrie, and Johns Island quadrangles have yielded U/Th ratios which indicate that this unit correlates with the Sangamon interglacial stage of 130 to 70 ka ago (Cronin and others, 1981; McCartan and others, 1982) and marine oxygen-isotope Stage 5 of Shackleton and Opdyke (1973). The Wando is poorly consolidated, easily excavated, and readily eroded. Clay-rich intervals may be quite sticky. Wando sand beds underwent extensive liquefaction to the south and west of this area during the 1886 Charleston earthquake (Dutton, 1889), but liquefaction features have not yet been found in this map area.

Holocene deposits.—Materials that have accumulated within the last 10 ka are not formally named. Some of these deposits (**Qhec**) formed in tidal marshes associated with estuaries that extended up the Cooper River estuary from the Silver Bluff Terrace of Colquhoun (1974), while others presently are forming in and around the modern Cooper River estuary (**Qht**). Round to ellipsoidal depressions (the largest of which could be considered "Carolina bays") commonly are filled with peat and muck deposits which date from the Wisconsinan glacial age to the present (Thornbury, 1965; Kaczorowski, 1977). These and other peat and muck deposits which accumulated along slack stream courses have been mapped as **Qhm**. Should the drainage system in these areas become better established naturally or artificially in the future, the peaty deposits can be expected to be destroyed by oxidation. For this reason, most of these peat deposits probably should be considered to be geologically ephemeral. Areas where sandy sediment seems to be actively prograding along stream courses have been mapped separately as **Qal**. Thin deposits of very fine grained, wind-blown sand exist also, but are localized and too poorly exposed to be mapped. All of these types of deposits were designated as unit **Q1** by McCartan and others (1984). Although materials beneath the Silver Bluff Terrace are compacted moderately well, the other Holocene deposits are unconsolidated and saturated with water.

The deposits beneath the Silver Bluff Terrace previously have been considered to represent the uppermost Sangamon stage (marine oxygen-isotope Stage 5A) or middle Wisconsinan stage (marine oxygen-isotope Stage 3) (Colquhoun, 1974), but they are at least locally middle Holocene. Woody material from 5 ft (1.5 m) below this surface in the Fort Moultrie quadrangle yields carbon-14 ages of 7,860 ± [illegible] years (U.S. Geological Survey Radiocarbon Laboratory Report W–5038, 1982) and of 6,960 ± 200 years (W–5322, 1984). Material from deep beneath the modern marshes surrounding the Cooper River yields ages only as old as 5 ka (Cinquemani and others, 1982). The peats and mucks are thin, but many were deposited as long ago as middle or early Holocene time. At least one locality in the Ladson quadrangle contains wood in a much older peat deposit which yields a carbon-14 age of 34,100 ± 700 years BP (W–5388, 1984).

GEOLOGIC HISTORY

The area of this map has been inundated repeatedly by marginal-shelf seas of the Atlantic Ocean since Late Cretaceous time. A summary of the lithostratigraphy and biostratigraphy of the materials which accumulated during Late Cretaceous and early Tertiary marine transgressions is presented by Gohn and others (1977) and Hazel and others (1977). These older deposits occur in this map area only in the subsurface (65 to 3,300 ft or 20 to 1,000 m below sea level).

The oldest unit penetrated by auger drilling within 65 ft (20 m) of the surface is the middle Eocene Cross Member of the Santee Limestone. This unit was penetrated in the shallow subsurface only in the northern half of the map area. At the time of deposition of the Cross Member, this area was located on the continental shelf under open marine waters, far to the east of the present Atlantic shoreline. The sandy texture and diverse fossil assemblage indicate that the ocean bottom during Cross time was firm but unlithified and inhabited by a normal benthic-marine shelf fauna. At the end of Cross time, the sea appears to have receded to the east of the present shoreline.

In the late Eocene, the sea again transgressed across the map area and began to deposit the Parkers Ferry Formation. At the time of deposition of this unit, the map area again was located on the continental shelf under open-marine waters, but the fine texture and restricted fossil assemblages of the Parkers Ferry indicate that the ocean bottom was soft and covered with calcareous ooze which was foraged and extensively bioturbated by echinoids. The Parkers Ferry contains the zeolite mineral clinoptilolite, which is considered to be an alteration product of volcanic ash (Gohn and others, 1977). No younger unit has yielded this mineral, though it does occur in older local units through the late Paleocene. Following deposition of the Parkers Ferry, the sea again withdrew eastward beyond the position of the present coastline.

The next known major transgression of the sea across the map area occurred in late Oligocene time, when the Ashley Formation was deposited. This unit also accumulated well offshore in an open-marine-shelf environment. During the deposition of the Ashley, however, fine carbonate sand, with subordinate quartz and phosphate sand, accumulated on the sea bottom. Foraminifera tests are abundant; mollusk, coral, and vertebrate remains occur sporadically. By the end of Ashley deposition, major tectonic subsidence ceased in the Charleston region. The end of Ashley deposition was marked by a regression of the sea, probably to the east of the present coastline.

During another late Oligocene transgression, probably 1–2 Ma later, the Chandler Bridge Formation was deposited (Sanders and others, 1982). This is a shallower and more clastic shelf deposit than the Ashley. The Chandler Bridge once contained abundant mollusk shells, but these have been largely leached out and only their casts and molds remain. Phosphatic vertebrate remains, which were not so affected by leaching, are abundant.

The sea withdrew again from the Charleston area during late Oligocene time to east of the present coastline and next transgressed across the outer Coastal Plain during very late Oligocene and very early Miocene time. During this transgression, the Edisto Formation, an impure quartz-rich limestone (Ward and others, 1979) which in some areas was extensively altered to rock phosphate, was deposited. Except for blocks of rock phosphate which have been reworked into the basal lag beds of younger units, the Edisto may be eroded completely from the map area. Small remnant patches of unaltered Edisto in normal stratigraphic position only are known to persist to the west in the Clubhouse Crossroads, Ridgeville, and Jacksonboro quadrangles.

During early Miocene (Burdigalian) time, the area was again inundated by marginal marine lagoons, in which were deposited phosphatic, fine-grained, attapulgite-rich, clayey sands and clays of the Marks Head Formation of Abbott and Huddlestun (1980). This unit has been found in the map area only in one hole in the Huger quadrangle (***HU–22***), but its widespread occurrence to the southwest, south, and southeast suggests it may have been present in this area but was stripped away by later erosion.

A late Miocene or early Pliocene transgression is suggested for the Charleston area on the basis of phosphatized vertebrate remains of late Miocene or early Pliocene ziphiid whales, present in the Pleistocene lag gravels in this region (Leidy, 1876, 1877). No deposits of this age have been discovered so far in either surface outcrops or auger holes.

A regional middle Pliocene transgression deposited the Goose Creek Limestone in a shallow-marine-shelf environment. Goose Creek sediment is abundant only east of the Cooper River in the map area, but probably once occurred as an extensive continuous cover of limestone over the entire area. The Goose Creek usually lies directly over the Ashley Formation. This suggests that the Miocene units were mostly stripped away in latest Miocene or earliest Pliocene time prior to deposition of the Goose Creek. Thus, by inference, a regression of the sea eastward beyond the present coastline occurred during late Miocene and (or) early Pliocene time. Similarly, because the Goose Creek was eroded from wide areas before deposition of the lower Pleistocene Waccamaw Formation, a late Pliocene to early Pleistocene regression must have occurred.

Only a few patchy areas of Waccamaw(?) Formation, tentatively correlated to the unit **Q6** (Waccamaw? Formation) of McCartan and others (1982), were discovered in this area, but the wide extent of this unit northwest of the map area indicates that deposits of a regional transgression about 1.5(?) Ma ago once were present but have been mostly stripped away. Younger Pleistocene deposits (the Daniel Island beds, the Penholoway Formation, the Ladson Formation, the Ten Mile Hill beds, and the Wando Formation) are still widespread in this area. These are associated with interglacial Pleistocene marine transgressions about 1.25 Ma, 850 ka, 450 ka, 200 ka, and 100 ka ago, respectively. In Daniel Island time, the sea probably transgressed inland only to about the present coastline. However, an extensive estuary system formed across most of the Huger, Bethera, and Cordesville quadrangles. This estuary system appears to have occupied an older Goose Creek channel system which was largely scoured out in late Pliocene and (or) early Pleistocene time. Remnant patches of the Goose Creek are found occasionally beneath the Daniel Island beds (see section ***B′-B″*** in Huger quadrangle). After Daniel Island time, the sea again withdrew to the east. The sea again transgressed entirely across the map area 850 ka ago to its northwest border and there deposited the Pinopolis-Summerville barrier. The sea withdrew seaward and then transgressed again into this area about 450 ka ago to deposit the Bethera barrier system that runs across the north-central portion of the map area. Northwest of this barrier system was a large lagoonal complex which partially filled with clayey sands (**Qlc**). When sea level dropped after thousands or tens of thousands of years, the pattern of the old tidal channel systems became the framework for the drainage system that now exists in that portion of the map area. About 200 ka ago, after a long interval during which the map area was above sea level, the sea again transgressed into this area only as far as the southeastern edge of the map area to deposit the Cainhoy barrier system (**Qts**). Northwest of this barrier, an extensive series of marginal-marine deposits (**Qtc**) accumulated in a large back-barrier lagoon. When sea level dropped after this transgression, the old tidal estuaries became transformed into the streams that presently drain most of the southern half of the map area. The transgression in early Wando time did not leave any known deposits in the map area, and the late Wando sea transgressed inland only far enough to deposit the Mt. Pleasant barrier system well to the south in the Fort Moultrie quadrangle. All deposits of this age in the map area represent deposits which accumulated in estuaries and fresh-water swamps along the Cooper River and its tributaries. Deposits of Holocene age indicate similar depositional environments.

TECTONICS

This map area lies east of the center of the meizoseismal region of the 1886 Charleston earthquake. Even so, the distribution of thicker Oligocene deposits in the northwestern part of the map suggests that a tectonic trough may be present in that area which is underlain by basement rocks with low magnetic intensity (U.S. Geological Survey, 1975). Cross section **C-C′** in the Cordesville quadrangle shows that the Tertiary sediments in that area dip southwest, which is regionally anomalous, and that the upper Oligocene Chandler Bridge Formation is unusually close to the upper Eocene Parkers Ferry Formation near the southwest end of that cross section. This strongly suggests that the Eocene-Oligocene contact in the west-central part of the map area may be controlled by a buried fault along which relative movement was up on the southwest side. The fact that the West Branch of the Cooper River runs next to this inferred fault on its downthrown side also suggests that this feature has been actively downwarping in Pleistocene time. At the present, however, there is no known seismic activity along this feature.

Another feature which appears to be tectonic is the subrectangular area of Parkers Ferry Formation in the subsurface that is located just north of the East Branch of the Cooper River in the northeastern quarter of the Kittredge quadrangle. The Parkers Ferry is present at much higher elevations in this quarter than in the area immediately surrounding it; in addition, this area represents a local high on the base of the Pleistocene structure contours. This evidence suggests that this feature also has been actively moving upward as late as Pleistocene time. Although there is no evidence at present of seismic activity within this feature, a magnetic survey of the Charleston area revealed that this feature is underlain by a strongly positive magnetic anomaly (U.S. Geological Survey, 1975). The anomaly suggests a tectonic origin rather than an erosional or depositional origin for this feature.

ECONOMIC GEOLOGY AND WATER RESOURCES

Phosphate, chiefly concentrated as a lag bed at the base of the Wando Formation, was widely mined about 10 mi (15 km) to the southwest of this map area in the Johns Island and Ladson quadrangles from 1867 to 1937 (Malde, 1959). The only records of mining in the map area indicate that portions of the East Branch of the Cooper River were dredged for detrital rock phosphate that was concentrated on the river bottom (Penrose, 1888). Rock phosphate occurs at Rock Hole near the southern border of the Bethera quadrangle (Eric Force, written commun., 1984), but there is no known economic potential for this resource in the area at the present time. Only slight potential exists for extracting uranium from the phosphate-rich lag gravels at the base of the various Quaternary units (Force and others, 1978), and increased property values due to urban expansion from Charleston has reduced this slight potential even more. The Edisto Formation is the probable parent lithology for most of the rock phosphate (Sloan, 1908).

Bricks were manufactured before the Civil War on Medway Plantation, southwest of Back River, north of Prioleau Creek, and east of the Seaboard Coast Line in the southwest corner to the Kittredge quadrangle. These clay and clayey sand deposits probably are developed mostly in the middle Holocene (**Qhec**). They still are considered to have potential for brick manufacture and for lightweight aggregate raw material (Robinson and Johnson, 1960).

Sand and earth fill are the only mineral resources presently exploited in the area (Long and others, 1980). The barrier sands contain the purest sands, while the back-barrier deposits contain variable amounts of clay. Both deposits are excavated by strip mining. The coarse river sands in the Bethera quadrangle have not yet been exploited, but they have good economic potential if their depth does not render them economically inaccessible. Locations of many borrow pits are mapped, but others probably exist which escaped detection.

The Quaternary units are generally saturated with and occasionally are tapped for fresh water. Most drinking water that comes from shallow wells in this area comes from the Goose Creek Limestone, though deeper and more reliable aquifers are found in the Santee Limestone and the underlying Paleocene Black Mingo Formation. These deeper aquifers may be under enough pressure to be artesian.

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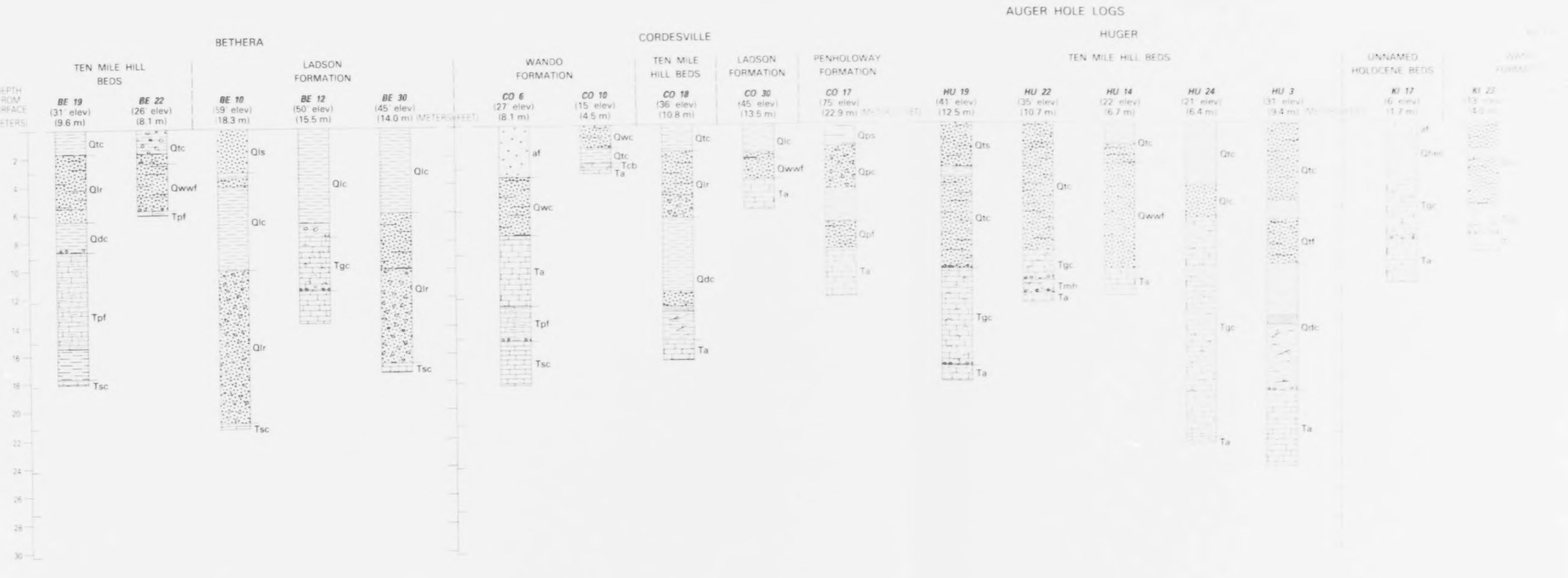

FIGURE 3.—Isopach map showing

interval 10 feet (approximately 3 meters)

GEOLOGY OF THE BETHERA, CORDESVILLE, HUGER, AND KITTREDGE QUADRANGLES, BERKELEY COUNTY, SOUTH CAROLINA

By

Robert E. Weems and Earl M. Lemon, Jr.

1989

Formation.—The Ladson sands, clays, and clayey sands present in the type section (Malde, 1959) upper Talbot terrace northwest of the Bethera scarp (Colquhoun, 1974). This unit is equivalent McCartan and others (1984). The present elevation of the top of the lagoonal deposits included indicates that the Ladson was deposited at a time when sea level in the Charleston area stood (15 m) above its present level relative to the land. At the time of maximum transgression, the marked by an elongate barrier island (the Bethera barrier) which now forms the sand deposits in the northeastern portion of the map area. The crest of this feature is at an elevation ft (18–19 m) above sea level, except where it overlies deep filled Pleistocene channels. In these anomalously low because the compaction of the underlying thick Pleistocene deposits has setting of the land. Whitten Bay, in the Bethera quadrangle, occupies one of these low- Creek, in the same quadrangle, has a slightly different origin. There a modern stream has of an old filled channel that produced a low-lying area in the Bethera barrier. Immediately of the Bethera barrier, the ancestral Santee River was apparently entrenched in a diagonally across the Bethera quadrangle from the north border southeastward to the east subsequently buried by Ladson sediments, contains thick, coarse-grained, feldspathic (Qlr) at its base. Near the time of maximum transgression of the shoreline during deposition the Santee built its level above its filled valley and migrated southward to a course the present Cooper River valley. There it spread clayey, coarse-grained sand and feldspathic delta front and adjacent lagoons in the north-central and western portions of the map Ladson time, however, the ancestral Santee must have migrated back to the north, where its present channel north of this map area when sea level dropped again at the end 1). Back-barrier clays of the Ladson Formation in the Stallsville quadrangle have normal (Liddicoat and others, 1981), so they must be younger than 730 ka. Corals from the next Ten Mile Hill beds, have yielded U/Th ratios which indicate that those beds are 200 to 240 the age of the Ladson must be between 240 and 730 ka. The Ladson Formation may Canepatch Formation of DuBar (1971), which has yielded U/Th ratios suggesting an age the vicinity of Myrtle Beach, S. C. (Cronin and others, 1981). Because the name Ladson over the name Canepatch. The Ladson is poorly consolidated, easily excavated, and intervals may be quite sticky.

—The clays and clayey sands here included in the Ten Mile Hill beds were deposited that existed landward of a barrier beach, the sands of which now constitute Ten Mile deposits formerly were included in the Ladson Formation by Malde (1959) because they environments, but they are mapped separately in this report because they record a younger of the sea than that recorded by the beds forming the Ladson type section. Malde Ten Mile Hill" (a term previously used by Sloan, 1908), but not the associated lagoonal unit younger than the Ladson Formation. The name is modified here to "Ten Mile Hill to include the deposits in the back-barrier and shallow-shelf environments that existed beach that once occupied the present position of Ten Mile Hill. The Ten Mile Hill beds, the lower Talbot terrace southeast of the Bethera scarp (Colquhoun, 1974) and are of McCartan and others (1984). The Ten Mile Hill beds were deposited at a time when area stood about 35 ft (11 m) above its present level relative to the land as indicated of the top of the lagoonal deposits associated with this unit. The Cainhoy barrier of sands of the Ten Mile Hill beds, is present only in the southeastern corner of (Qts) and marks the southeastward margin of the outcrop belt of these deposits. The this barrier is about 50 ft (15 m) above sea level. Northwest of this barrier, clay-rich Ten (Qtc) formed in back-barrier to estuarine environments. The coarse, angular fluvial sands, component of the Ladson back-barrier deposits, are absent from this unit except into the basal few feet. Corals recovered by the authors from marine deposits of the the Ravenel and Johns Island quadrangles yielded U/Th ratios which indicate that the between 200 and 240 ka ago (Cronin and others, 1981; McCartan and others, 1982). This marine oxygen-isotope Stage 7 of Shackleton and Opdyke (1973). The Ten Mile Hill beds easily excavated, and readily eroded. Clay-rich intervals may be quite sticky. The Ten the well-sorted sands around Ten Mile Hill, underwent extensive liquefaction during earthquake.

—The Wando Formation is defined by McCartan and others (1980) as beds of sand, which underlie the Pamlico and Princess Anne Terraces of Colquhoun (1974). This unit Q2 by McCartan and others (1984). The Wando was deposited when sea level in the about 25 ft (7.5 m) (as indicated by the Pamlico terrace) and 15 ft (4.5 m) (as indicated terrace) above its present level relative to the land. In the map area, Wando deposits are lower high-sea-level stand. The sea did not transgress inland as far as this area, but it an extensive system of estuaries along the Cooper River. These estuaries then became partly clayey sand (Qwc) to elevations as high as 15 ft (4.5 m) above present sea level. The beneath Biggin Swamp are probably the source of the mammoth and mastodon remains that eighteenth century, during the construction of the Santee-Cooper Canal (Drayton, 1802). from marine beds of the Wando in the Cainhoy, Fort Moultrie, and Johns Island yielded U/Th ratios which indicate that this unit correlates with the Sangamon interglacial ka ago (Cronin and others, 1981; McCartan and others, 1982) and marine oxygen-isotope and Opdyke (1973). The Wando is poorly consolidated, easily excavated, and readily intervals may be quite sticky. Wando sand beds underwent extensive liquefaction to the south during the 1886 Charleston earthquake (Dutton, 1889), but liquefaction features have in this map area.

deposits.—Materials that have accumulated within the last 10 ka are not formally named. Some (Qhec) formed in tidal marshes associated with estuaries that extended up the Cooper River Silver Bluff Terrace of Colquhoun (1974), while others presently are forming in and around River estuary (Qht). Round to ellipsoidal depressions (the largest of which could be bays") commonly are filled with peat and muck deposits which date from the Wisconsinan the present (Thornbury, 1965; Kaczorowski, 1977). These and other peat and muck deposits along slack stream courses have been mapped as Qhm. Should the drainage system in become better established naturally or artificially in the future, the peaty deposits can be expected by oxidation. For this reason, most of these peat deposits probably should be considered to ephemeral. Areas where sandy sediment seems to be actively prograding along stream courses separately as Qal. Thin deposits of very fine grained, wind-blown sand exist also, but are poorly exposed to be mapped. All of these types of deposits were designated as unit Q1 by others (1984). Although materials beneath the Silver Bluff Terrace are compacted moderately Holocene deposits are unconsolidated and saturated with water.

beneath the Silver Bluff Terrace previously have been considered to represent the uppermost (marine oxygen-isotope Stage 5A) or middle Wisconsinan stage (marine oxygen-isotope Stage 1974), but they are at least locally middle Holocene. Woody material from 5 ft (1.5 m) below the Fort Moultrie quadrangle yields carbon-14 ages of 7,860 ± years (U.S. Geological Survey Laboratory Report W-5038, 1982) and of 6,960 ± 200 years (W-5322, 1984). Material from the modern marshes surrounding the Cooper River yields ages only as old as 5 ka (Cinquemani 1982). The peats and mucks are thin, but many were deposited as long ago as middle or early At least one locality in the Ladson quadrangle contains wood in a much older peat deposit carbon-14 age of 34,100 ± 700 years BP (W-5388, 1984).

GEOLOGIC HISTORY

of this map has been inundated repeatedly by marginal-shelf seas of the Atlantic Ocean since time. A summary of the lithostratigraphy and biostratigraphy of the materials which during Late Cretaceous and early Tertiary marine transgressions is presented by Gohn and others Hazel and others (1977). These older deposits occur in this map area only in the subsurface (65 to 1,000 m below sea level).

unit penetrated by auger drilling within 65 ft (20 m) of the surface is the middle Eocene Cross Santee Limestone. This unit was penetrated in the shallow subsurface only in the northern half area. At the time of deposition of the Cross Member, this area was located on the continental shelf marine waters, far to the east of the present Atlantic shoreline. The sandy texture and diverse fossil indicate that the ocean bottom during Cross time was firm but unlithified and inhabited by a normal shelf fauna. At the end of Cross time, the sea appears to have receded to the east of the present

Eocene, the sea again transgressed across the map area and began to deposit the Parkers Ferry the time of deposition of this unit, the map area again was located on the continental shelf under waters, but the fine texture and restricted fossil assemblages of the Parkers Ferry indicate that the was soft and covered with calcareous ooze which was foraged and extensively bioturbated by Parkers Ferry contains the zeolite mineral clinoptilolite, which is considered to be an alteration ash (Gohn and others, 1977). No younger unit has yielded this mineral, though it does local units through the late Paleocene. Following deposition of the Parkers Ferry, the sea again beyond the position of the present coastline.

known major transgression of the sea across the map area occurred in late Oligocene time, when Formation was deposited. This unit also accumulated well offshore in an open-marine-shelf During the deposition of the Ashley, however, fine carbonate sand, with subordinate quartz and accumulated on the sea bottom. Foraminifera tests are abundant; mollusk, coral, and vertebrate sporadically. By the end of Ashley deposition, major tectonic subsidence ceased in the Charleston of Ashley deposition was marked by a regression of the sea, probably to the east of the present

late Oligocene transgression, probably 1–2 Ma later, the Chandler Bridge Formation was and others, 1982). This is a shallower and more clastic shelf deposit than the Ashley. The contained abundant mollusk shells, but these have been largely leached out and only remain. Phosphatic vertebrate remains, which were not so affected by leaching, are

again from the Charleston area during late Oligocene time to east of the present coastline across the outer Coastal Plain during very late Oligocene and very early Miocene time. the Edisto Formation, an impure quartz-rich limestone (Ward and others, 1979) which extensively altered to rock phosphate, was deposited. Except for blocks of rock phosphate reworked into the basal lag beds of younger units, the Edisto may be eroded completely from small remnant patches of unaltered Edisto in normal stratigraphic position only are known to in the Clubhouse Crossroads, Ridgeville, and Jacksonboro quadrangles.

Miocene (Burdigalian) time, the area was again inundated by marginal marine lagoons, in phosphatic, fine-grained, attapulgite-rich, clayey sands and clays of the Marks Head Abbott and Huddlestun (1980). This unit has been found in the map area only in one hole in HU-22), but its widespread occurrence to the southwest, south, and southeast suggests present in this area but was stripped away by later erosion.

or early Pliocene transgression is suggested for the Charleston area on the basis of remains of late Miocene or early Pliocene ziphiid whales, present in the Pleistocene lag (Leidy, 1876, 1877). No deposits of this age have been discovered so far in either surface

middle Pliocene transgression deposited the Goose Creek Limestone in a shallow marine-shelf Creek sediment is abundant only east of the Cooper River in the map area, but probably an extensive continuous cover of limestone over the entire area. The Goose Creek usually the Ashley Formation. This suggests that the Miocene units were mostly stripped away in latest Pliocene time prior to deposition of the Goose Creek. Thus, by inference, a regression of beyond the present coastline occurred during late Miocene and (or) early Pliocene time. the Goose Creek was eroded from wide areas before deposition of the lower Pleistocene a late Pliocene to early Pleistocene regression must have occurred.

areas of Waccamaw(?) Formation, tentatively correlated to the unit Q6 (Waccamaw? McCartan and others (1982), were discovered in this area, but the wide extent of this unit indicates that deposits of a regional transgression about 1.5(?) Ma ago once were mostly stripped away. Younger Pleistocene deposits (the Daniel Island beds, the the Ladson Formation, the Ten Mile Hill beds, and the Wando Formation) are still These are associated with interglacial Pleistocene marine transgressions about 1.25 Ma, ka, and 100 ka ago, respectively. In Daniel Island time, the sea probably transgressed the present coastline. However, an extensive estuary system formed across most of the Cordesville quadrangles. This estuary system appears to have occupied an older Goose which was largely scoured out in late Pliocene and (or) early Pleistocene time. Remnant Goose Creek are found occasionally beneath the Daniel Island beds (see section B–B′ in Huger Daniel Island time, the sea again withdrew to the east. The sea again transgressed entirely 850 ka ago to its northwest border and there deposited the Pinopolis-Summerville barrier eastward and then transgressed again into this area about 450 ka ago to deposit the Bethera across the north-central portion of the map area. Northwest of this barrier system was a which partially filled with clayey sands (Qlc). When sea level dropped after thousands of years, the pattern of the old tidal channel systems became the framework for the exists in that portion of the map area. About 200 ka ago, after a long interval during was above sea level, the sea again transgressed into this area only as far as the southeastern to deposit the Cainhoy barrier system (Qts). Northwest of this barrier, an extensive series deposits (Qtc) accumulated in a large back-barrier lagoon. When sea level dropped after old tidal estuaries became transformed into the streams that presently drain most of the map area. The transgression in early Wando time did not leave any known deposits in late Wando sea transgressed inland only far enough to deposit the Mt. Pleasant barrier in the Fort Moultrie quadrangle. All deposits of this age in the map area represent in estuaries and fresh-water swamps along the Cooper River and its tributaries. indicate similar depositional environments.

TECTONICS

of the center of the meizoseismal region of the 1886 Charleston earthquake. Even Oligocene deposits in the northwestern part of the map suggests that a tectonic in that area which is underlain by basement rocks with low magnetic intensity (U.S. Cross section C–C′ in the Cordesville quadrangle shows that the Tertiary sediments which is regionally anomalous, and that the upper Oligocene Chandler Bridge to the upper Eocene Parkers Ferry Formation near the southwest end of that cross that the Eocene-Oligocene contact in the west-central part of the map area may fault along which relative movement was up on the southwest side. The fact that the River runs next to this inferred fault on its downthrown side also suggests that this downwarping in Pleistocene time. At the present, however, there is no known seismic

appears to be tectonic is the subrectangular area of Parkers Ferry Formation in the just north of the East Branch of the Cooper River in the northeastern quarter of the Parkers Ferry is present at much higher elevations in this quarter than in the area In addition, this area represents a local high on the base of the Pleistocene structure suggests that this feature also has been actively moving upward as late as Pleistocene evidence at present of seismic activity within this feature, a magnetic survey of the that this feature is underlain by a strongly positive magnetic anomaly (U.S. Geological suggests a tectonic origin rather than an erosional or depositional origin for this

ECONOMIC GEOLOGY AND WATER RESOURCES

concentrated as a lag bed at the base of the Wando Formation, was widely mined about southwest of this map area in the Johns Island and Ladson quadrangles from 1867 to The only records of mining in the map area indicate that portions of the East Branch of dredged for detrital rock phosphate that was concentrated on the river bottom (Penrose, occurs at Rock Hole near the southern border of the Bethera quadrangle (Eric Force, but there is no known economic potential for this resource in the area at the present exists for extracting uranium from the phosphate-rich lag gravels at the base of the (Force and others, 1978), and increased property values due to urban expansion from this slight potential even more. The Edisto Formation is the probable parent lithology phosphate (Sloan, 1908).

manufactured before the Civil War on Medway Plantation, southwest of Back River, north of of the Seaboard Coast Line in the southwest corner to the Kittredge quadrangle. These deposits probably are developed mostly in the middle Holocene (Qhec). They still are potential for brick manufacture and for lightweight aggregate raw material (Robinson and

are the only mineral resources presently exploited in the area (Long and others, 1980). contain the purest sands, while the back-barrier deposits contain variable amounts of clay. exploited by strip mining. The coarse river sands in the Bethera quadrangle have not yet they have good economic potential if their depth does not render them economically many borrow pits are mapped, but others probably exist which escaped detection. units are generally saturated with and occasionally are tapped for fresh water. Most from shallow wells in this area comes from the Goose Creek Limestone, though aquifers are found in the Santee Limestone and the underlying Paleocene Black deeper aquifers may be under enough pressure to be artesian.

0 1 2 3 KILOMETERS

1:24 000

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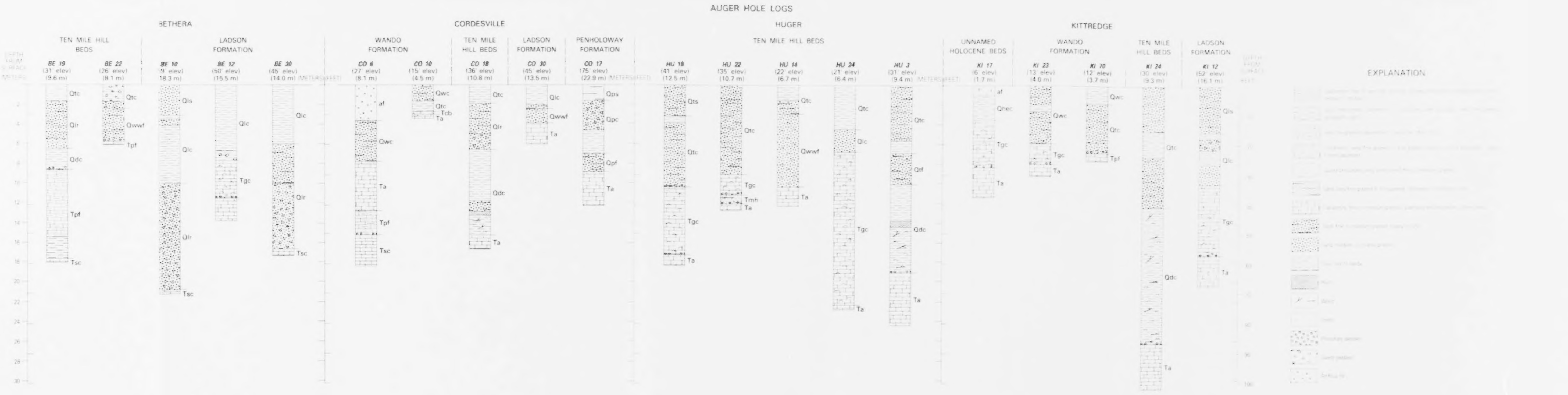
FIGURE 3.—Isopach map showing thickness of poorly consolidated Quaternary deposits. Contour interval 10 feet (approximately 3 meters). Thickness at drill hole localities in feet.



GEOLOGY OF THE BETHERA, CORDESVILLE, HUGER, AND KITTREDGE QUADRANGLES, BERKELEY COUNTY, SOUTH CAROLINA

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